Mechanical Drawing *for* High Schools

BOOK II

ADVANCED COURSES

(*a*) Shadow Projection—Linear Perspective (*b*) Machine Drawing
(*c*) Architectural Drawing

BY

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FOURTH YEAR

INTRODUCTION.

Upon entering his fourth year, the student may elect one of the three following courses:

Course A. Shadow Projections, and Linear Perspective.

Course B. Machine Drawing and Construction.

Course C. Architectural Drawing and Construction.

The purpose of these courses is not only to provide the student with an opportunity to turn to practical account the drafting skill and knowledge he has already acquired, but also to acquaint him with those "every day" facts of the subjects of higher draftsmanship, of machinery, and of architecture which, besides being of interest to almost every man, will be especially valuable to him as a basis for advanced study if he contemplates pursuing a technical profession.

And, incidentally, these courses will open to the student a glimpse of that great industrial world in which it may please him soon to play an active part.

Percy H. Sloan, Chairman.
Berthe E. Spink
Carl Durand
Albert W. Evans
Fred W. Zimmermann

COURSE A.

SHADOW PROJECTIONS—(Shades and Shadows)

By Berthe E. Spink.

Introductory Text.

"Shades and Shadows" is a conventional method of giving an appearance of reality to the orthographic projections of an object by tinting them in accordance with the amount of dark and light on its surfaces, and by establishing the shadow cast by the object upon one or more of the planes of projection, perhaps upon itself in part and upon other objects.

The subject might be called "oblique projection," for the projectors are oblique to the planes of projection. In practice shades and shadows is used principally by architectural draftsmen in the careful execution of elevations and perspectives of important buildings.

According to the custom we will place the problems in the first angle instead of in the third angle of projection, because it permits a more complete and natural rendering of the shadows. In this, the horizontal plane is below, and the vertical plane behind the objects; hence the positions of the views will be reversed from those with which we are familiar; that is, the top view now will be below and the front view above H. A., etc.; otherwise the processes are unchanged from those previously employed, and the results are practically the same.

As heretofore, the source of light is assumed at an infinite distance (above, back, and to the left of the draftsman); hence all rays emanating therefrom are parallel straight lines. The direction of the rays is arbitrary. We will adopt that usual and most convenient, to-wit, parallel with the diagonal of a cube the sides of which are parallel with the planes of projection. Now, although any such ray would make actually an angle of but 35 degrees, 16 minutes, with each plane, its projections will form each an angle of 45 degrees with H. A., whence the convenience of the direction selected, as will be understood more fully with the progress of the work. The objects are assumed as opaque.

Perspective sketch showing the process of obtaining the shadow of an object from its orthographic projections.

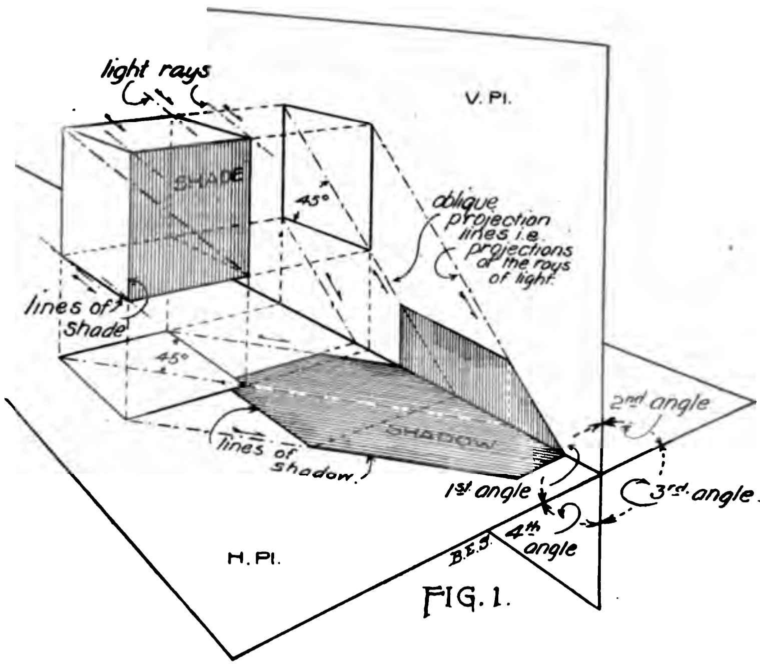


FIG. 1.

Under such conditions as these it is evident that the object will be divided into an illuminated and a

dark portion (the one towards, the other from the source of light), and that it will cast a definite shadow. These three are called respectively "the light," "the shade," and "the shadow."

The line of demarcation of the shade is called "the line of shade." It is established by locating the points of tangency of the rays of light with the surfaces of the object, and connecting them. It will be readily seen that, if the same rays used to determine the line of shade be extended until intercepted by the planes of projection or some intervening surface, we thereby shall have fixed the outline of the shadow cast by the object. This outline, called "the line of shadow," is then really but the shadow of the line of shade, its oblique projection, found by the use of oblique projectors—namely, the rays of light—which, as before stated, appear at 45 degrees to H. A.

Let us take a simple example; to find the shadow of a given point. This is the same problem as to find the point of penetration or trace in a given surface of a given line passed through a given point.

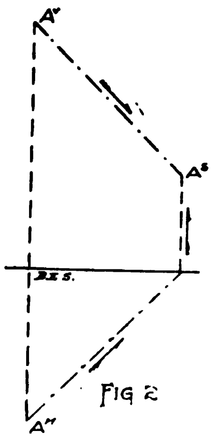


FIG 2

Figure 2 illustrates the method of obtaining this. The elevation of the point is A^V, and its plan A^H. Drawing the projections of the ray passing through the point, we find that its trace occurs in V in the point A^S. This is the shadow of the given point. If the point had been assumed lower or further forward, its shadow might have fallen upon H, but the process of locating it would have been the same, merely inverted. From this we derive the following:

Rule 1. The shadow of a point on any surface will be the trace in that surface of a ray passed through the given point.

From the preceding it follows that to find the shadow of a straight line, locate the shadows of its extremities, and if these fall in the same plane, join them. If, however, they fall in different planes, find the shadow of any intermediate point, and pass a line through the two shadows lying in the same plane to its intersection with H. A. Join the point thus found with the shadow of the second extremity. In like manner, but requiring more points, the shadow of a curve would be found. It should be evident from this that:

Rule 2. The shadow of a straight line on a surface will be the trace in that surface of a plane of rays passed through the given line.

In Figure 3, the shadow of the intermediate point **C** was found to fall in H. in the point $\mathbf{C}^S$. Passing a line through $\mathbf{B}^S$ $\mathbf{C}^S$ to its cutting of H. A., we obtain a point, **X**, which we may properly connect with $\mathbf{A}^S$, for they both lie in V. The trace of the plane of rays through the line **A-B** (i. e., its shadow) in H. and V., is $\mathbf{A}^S$-**X**-$\mathbf{B}^S$.

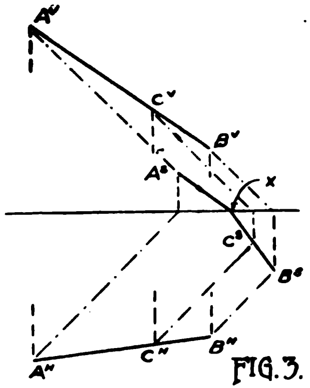


FIG. 3.

From Rule 2 it follows:

That only points situated in the same plane can be connected.

That the shadows of two points within it will determine the direction of the shadow of a straight line on any plane.

That the shadow of a line on a plane with which it is parallel is a line which is equal to and parallel with the given line.

That the shadow of parallel lines on the same plane are parallel.

That the shadow of a line that is perpendicular to V. on V., or on the elevation of any object, will be a line at 45 degrees left to H. A.

That the shadow of a line that is perpendicular to H. on H., or on the plan of any object, will be a line at 45 degrees left to H. A.

In accordance with Rule 1—to find the shadow of an angular figure we have but to determine the traces of the rays passed through its angles, and to join them. But—Rule 2—the line of shadow thus found is made up of the traces of the planes of rays passed through the sides of the figure. Further thought makes it clear that really these planes of rays form a prism of rays, and that the shadow of the figure is then but the line of penetration of this prism with an intercepting surface.

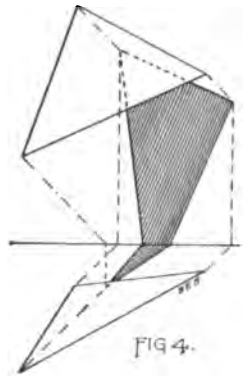


FIG 4.

This prism of darkness is called "the umbra." The umbra of any angular plane figure (unless one projection of it is at 45 degrees L. to H. A., and the figure actually perpendicular to the opposite plane) will always be a prism, and that of a circle will always be a cylinder, excepting under the above conditions. A little further consideration makes it evident that all planes and all solids also have umbra back and below them, whence:—

Rule 3. The shadow of a plane figure or of a solid is the line of penetration or the trace of its umbra with the planes of projection, or with intervening surfaces.

From this it follows that the shadow of any figure upon a plane with which it is parallel, will be a similar and equivalent figure.

Now, no matter in what various ways we may consider the line of shadow to be derived, not forgetting that the line of shadow is the shadow of the line of shade, the general method of establishing it is this:

Rule 4. The shadow of the line of shade upon any surfaces may be found by determining the traces in those surfaces of a sufficient number of rays of light passed through a like number of points in the line of shade, and then connecting them.

This rule applies alike to the finding of shadows upon plane and curved surfaces, and upon the planes of projection and those intervening. But to obtain those necessary traces of the rays, we must often resort to the use of auxiliary views and sectional planes (planes of rays). Thus we see that Shadow Projection is but a continuation of the subject of Penetrations, and, of course, the same methods of solution are applicable to both.

Very often it happens that a shadow is interrupted by falling upon two intersecting planes, as the planes of projection, for example. The exact points in which the line of shadow is cut by H. A. are then needed. To fix these, usually, the traces of rays must be found either with V. below H., or with H. back of V. In Figure 5, assume that the shadow of a point, the projections of which are **A^V** and **A^H**, is wanted on H. A trace of the ray through the given point occurs in V. in **A^{VS}**, the distance **b-A^{VS}** above H. Then, as **A^{VS}** is the point in which the ray actually penetrates V., any farther extension of its projections must be back of V. Continuing its elevation, as shown, to the point of intersection with H. A. in **C**, and extending its plan above H. A. to correspond, by projecting **up**

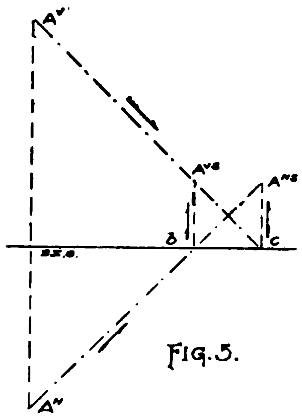


FIG. 5.

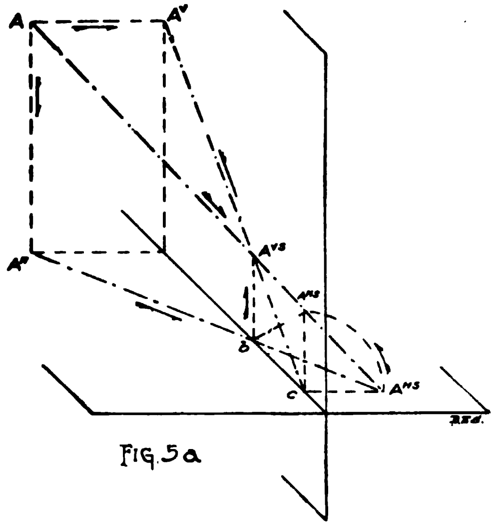


FIG. 5a

from **C** to the plan thus produced, we have in this point, **A^{HS}**, the trace of the ray in H.—i. e., the shadow of the given point on the horizontal plane. By joining this with any point of shadow lying in H. in front of V., we could fix the desired point of intersection of H. A. and the line of shadow, which point of intersection is the "break" in the outline of the shadow, such as appears in the shadow of the line, Figure 3. Figure 5a is a cabinet projection of Figure 5, which may help the student to a better understanding of the process just explained. By inverting Figure 5, we can illustrate the process of locating the shadow of a point in V. below H. The shadow of the line, Figure 3, could be found equally well in either of these ways.

In the solution of the following problems the student should first determine the line of shade, then establish the line of shadow, and finally ink and tint. In tinting, shades are to be determined in their tones as heretofore, allowance being made for atmospheric reflection on curved surfaces, etc. All shadows should be tinted flatly, and be of uniform depth. They should be as dark as the darkest tone of shade.

Problems.

Before undertaking the solution of the problems of Plate 1, as preparatory exercises therefor, the pupil should determine the shadows cast by a few lines and simple figures such as those shown in the illustrations, Figures 3 and 4, these to be in various positions relative to V. and to H.

The following are suggested:

1. Find the shadow of a line oblique to V. and to H. upon V.; upon H.; upon both V. and H., using the method shown in Figure 3; using the method shown in Figure 5.

2. Find the shadow of an irregular polygon which is parallel with V., on V.; parallel with H., on H.; inclined to either plane, on the opposite; inclined to both and upon both planes.

3. Using a circle, find its shadow when in the same positions given in Exercise 2.

After these, at the discretion of the teacher, the pupil may begin Plate 1. The location chart, Figure 6, gives the position in which each problem is to be drawn, and also the dimensions of each.

Plate 1—Fig. 6.

Problem A.—In the cube, the line of shade, beginning with the lower front corner, is **f-e-a-c-d-b-f**. If the shadows of these points are found, and they are connected in the order stated, the line of shadow will be completed.

Problem B.—In the pyramid, the left lateral faces are lighted, and the right ones and the base are in shade, hence the line of shade is **c-a-d-e-c**. If the shadows of these points are determined, and they are connected in the order stated, the shadow of the object will have been found.

Problem C.—The base being in H., it will cast no shadow. Determine the line of shade, lettering the points in it, find their shadows and complete the problem as before. In the elevation, the lateral edges make an angle of 75 degrees R. with H. A. Draw the plan of the lower base, then the elevation of the whole prism, and from this complete the plan.

Problem D.—In the oblique cylinder, first get the shadow of the axis, **a-b**, on H. See Figure 5. In the elevation, this axis is at an angle of 75 degrees L. to H. A. Now, inasmuch as the elements of the cylindrical surface are parallel with this axis, the shadow

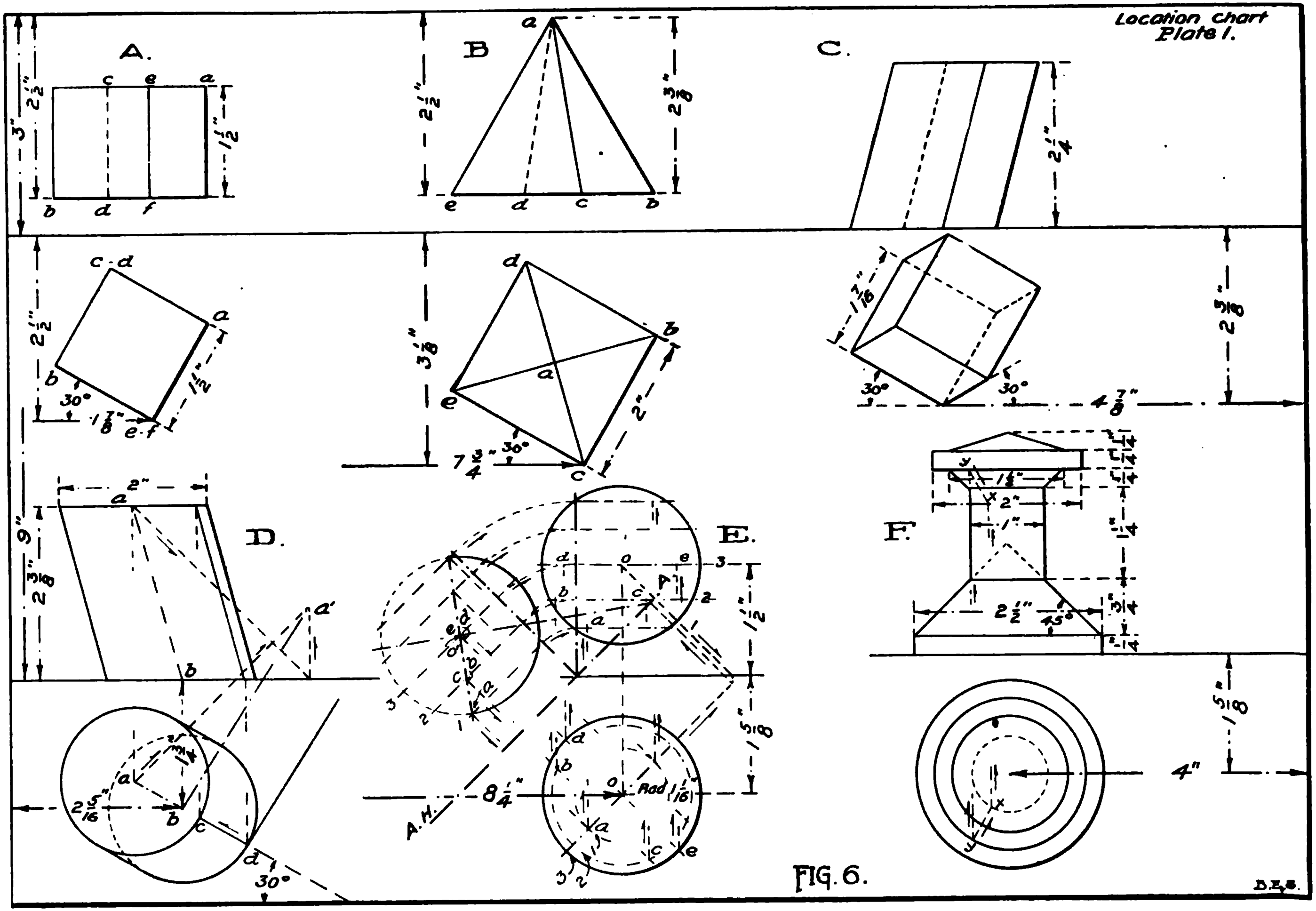


FIG. 6.

of that element, which is a part of the line of shade on the cylindrical surface, must be parallel with the shadow of the axis, Rule 2-d. Also this must be tangent to the base at the lower end of the line of shade, since the base lies in H. Drawing such a line parallel with the shadow of the axis, **a-b**, we find its point of tangency in **d**, from which the element of shade **d-c**, is drawn. Get the corresponding element of shade on the opposite side of the cylinder, and then complete the shadow by drawing the line of shadow of the rear half of the upper base.

Problem E.—To determine the line of shade on the sphere, a section at right angles to the actual direction of the light must be made, for it is evident that one hemisphere is lighted and the other shaded. For this section it is necessary to construct an auxiliary vertical plane, parallel with the light and at 45 degrees L. to V., assuming the auxiliary horizontal axis of projection (**A-H-A**) anywhere convenient. Now, find the trace in H. Pl. of a ray through the center of the sphere, **O**; transfer this point to **A-H-A**, and draw from it the auxiliary view of the ray through **O′**. The angle formed with **A-H-A** is the true angle of the light with H. Pl., 35 degrees, 16 minutes. In the auxiliary view, perpendicular to this ray, pass the oblique sectional plane through the center **O′**. The outline of the resulting sectional surface, a great circle, will be the line of shade. By the use of zone lines, **1**, **2**, **3**, etc., transfer this to the top and front views. To get the cast shadow, proceed as before, Exercise 3.

Problem F.—A sheet iron ventilator. As the direction of the light is arbitrary, in this problem we will assume that it makes an angle of 60 degrees L. with H. A. on both planes instead of 45 degrees, as heretofore. The process of solution will not differ from that previously used.

Get the shadow cast by the hood upon the cylinder, and of the latter upon the frustum, before working out the shadow of the object upon the planes of projection. The method of obtaining the points for the shadow cast by the hood upon the cylinder, is shown by a ray drawn from point **y** to its trace in the cylindrical surface in **x**. All other points for this line are found in the same way. In a similar manner (by sectional planes) the shadow cast by the cylinder and hood upon the conical base is found.

To determine the line of shade on the frustum, get the shadow of its vertex, then, by the construction, "To draw two tangents to a circle from a point without," Prob. 1, Pl. 3, First Year, assuming the shadow of the vertex as the given point, draw tangents to the base of the frustum. These tangents will be part of the line of shadow, and the line of shade will be the elements drawn from the points of tangency to the vertex.

Once the line of shade is established, there should be no trouble in obtaining the shadow cast by the object upon the planes of projection.

Plate 2—Fig. 7.

Problem A.—Location chart, Figure 7. Place H. A. 6″ D.

To find the shadows cast by the various edges upon the different surfaces of the object, consider those surfaces merely as planes of projection, some oblique, some vertical, and then proceed accordingly.

To illustrate: If the shadow of the line **x-s** is wanted, a plane at 45 degrees L. to H. A. is passed

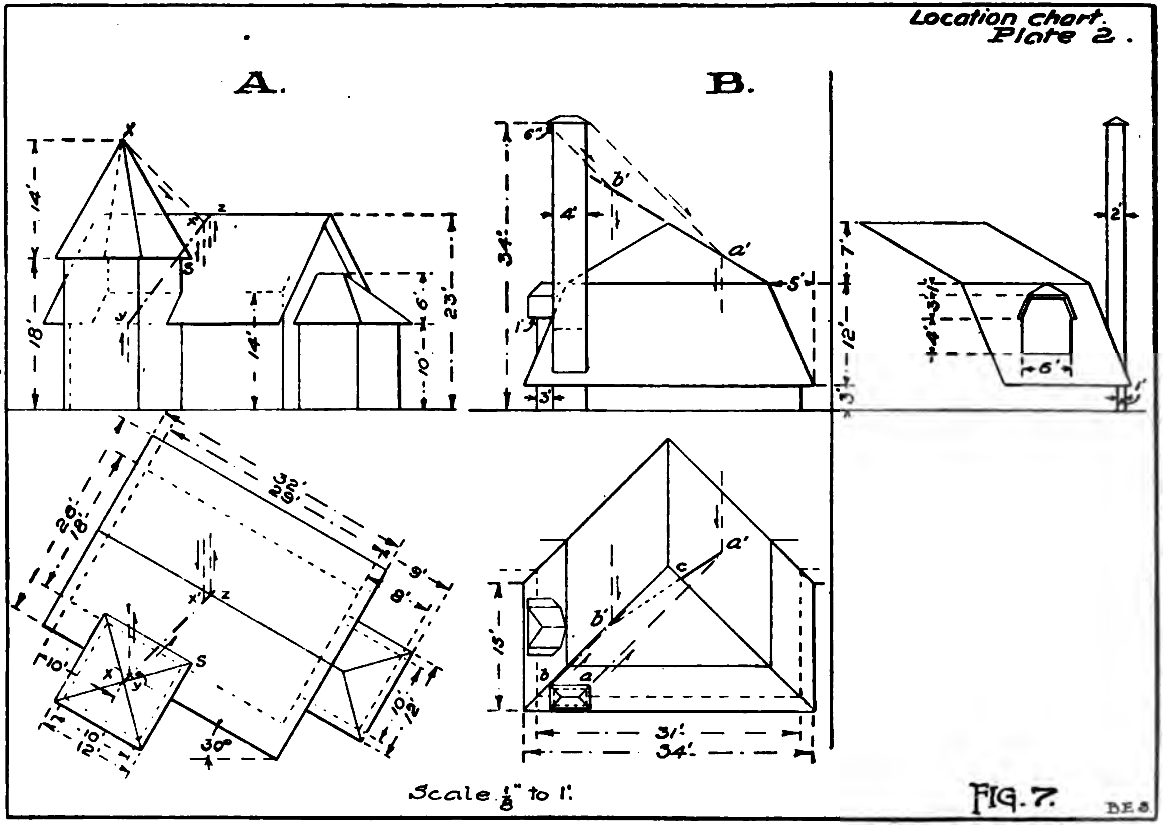


FIG. 7.

through the vertex of the spire, **x**, and continued through the adjacent side of the roof, cutting the latter in the trace **y-z**. The ray through **x** actually intersects this trace of the sectional plane in point **x′**, as shown in the elevation. Therefore, the point **x′** is the trace of the ray through point **x** in the roof surface—i. e., the shadow of point **x**.

In the same way, applying Rule 4, get the shadow cast by point **s**, and so determine the shadow of the line **x-s**. Similarly the shadows of all other edges may be secured. Besides the shadows upon the object, find its shadow upon H. Pl.

This problem may be varied readily by changing the direction of the light, by changing the dimensions

and positions of the various parts of the combination, by changing the pitch of the roofs, or by substituting a hip or a curb roof for the gable.

Problem B.—Often a side view is used in place of sectional planes to aid in securing shadows. Place V. A. 12½″ R.

In this problem the shadow of the hood of the chimney will fall partly upon the upper, front roof plane, and partly upon the upper, side roof plane if the chimney is shortened somewhat. That on the front roof plane then would be located first upon the side view, and thereafter projected to the front and top views, while the other would be found directly on the view by the process shown. For example: if the shadow of edge **a-b** is wanted, find the trace of a ray through point **a** as **a′** in the upper, side roof plane. The trace of the ray through point **b** would be in the upper, front roof plane, which point properly could not be connected with **a′** because the two points do not lie in the same plane. If, however, the upper, side roof plane be extended, as shown by the heavy dashed line, and the trace of the ray through **b** be found in it, this point, **b′**, may be connected with **a′**, thus giving in part, **a′-c**, the correct shadow of the edge **a-b**. In other particulars the problem does not vary from the preceding ones. In the side view, note that the projections of the rays of light are at 45 degrees R. to H. A. instead of 45 degrees L.

This example may be changed easily by setting the chimney farther to the right, by shortening it, by placing a dormer in front, by substituting a hip roof for the curb roof, and by changing the direction of the light.

Also, an arrangement similar to that in Figure 1, Third Year, as well as various problems in penetrations, are excellent combinations for this work.

LINEAR PERSPECTIVE—(Conic Projection).

By Carl Durand.

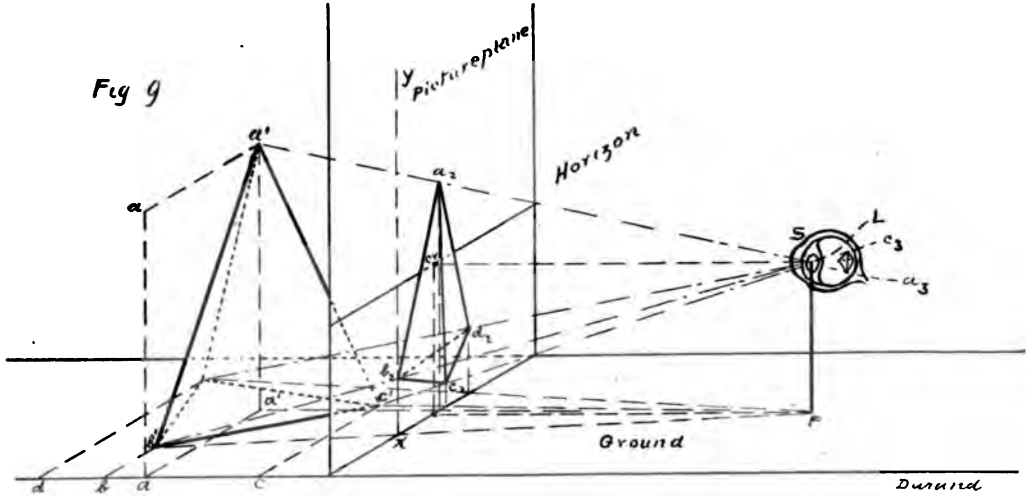
Introductory Text.

Broadly speaking, perspective is the art of giving an appearance of reality to the representations of objects.

Now, inasmuch as a surface has but two dimensions, the representation upon it of a form which has three dimensions, at first would seem to be impossible. However, if we examine the construction and the action of the eye, we will understand at once that such a picture readily may be made.

The eye is nearly a sphere, the exposed portion of which, the cornea, is a transparent glassy segment of slightly greater convexity than the hidden part. Back of the cornea is a colored diaphragm, the iris, in the center of which is the small round opening called the pupil. Behind the iris and pupil, suspended in a perfectly clear, gelatinous medium, is the lens, while the inner hemisphere of the eyeball is enveloped in a membrane known as the retina. Upon the retina, in an inverted position, the image of whatever sends light to the eye, is projected as shown in Figure 9. By this same process an image is thrown upon the back plate of a photographic camera.

Fig 9



The picture upon the retina, transmitted to the mind by the optic nerve in an unexplained manner, is the link between the actual object and the mental impression of it. Then, our problem is to draw a picture the projection of which upon the retina will be the same as that from the object itself.

To elucidate the solution of this problem in simple, practical ways, easy to learn, ways whereby the pupil may make a perspective drawing without having an extensive knowledge of descriptive geometry, is the purpose of this little treatise. In other words, it is our endeavor here to present and to make plain the application of the most essential laws of perspective, in a nutshell, as it were.

In Figure 9, note that the rays of light from the pyramid **a′-b′-c′-d′**, to the eye, **S**, form a cone having its vertex in the lens, **L**. Also, that these rays cross in the vertex, thus forming an inverted image of the pyramid upon the retina.

Now, if the cone of light should be intersected by a plane, as shown, the sectional lines in this plane would represent a true image (projection) of the pyramid. Thus, as points **a^1**, **a^2**, **a^3**, **b^1**, **b^2**, **b^3**, etc., are in the same straight lines respectively, they coincide; consequently (the pyramid being removed) the image on the intersecting plane (the picture plane) will present the same appearance as does the pyramid itself.

Definitions.

The following definitions and rules should be read, but, at first, they should not be studied or memorized by the pupils; later, they should be looked up and

learned whenever their application occasions reference to them; only to facilitate this reference are they all printed on these first pages.

1. Perspective drawing is the art of representing upon a plane surface objects as they appear from a given point of view. It is of two kinds—viz., linear, and aerial, or tone and color perspective.

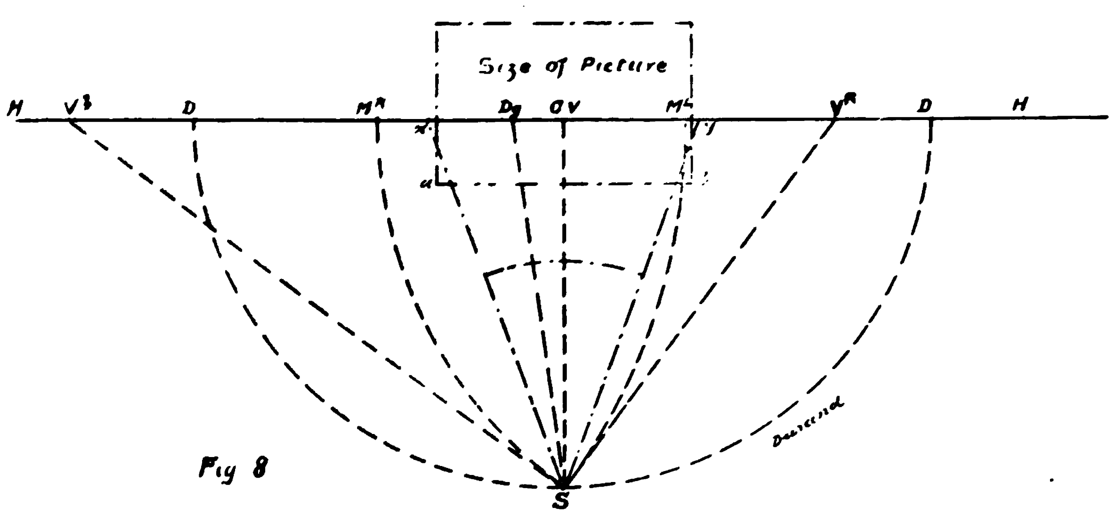


Fig 8

2. Linear perspective is the process of constructing mathematically the outlines of objects correct in appearance. To secure the results desired, its rules must be followed strictly.

3. Aerial perspective is the process of giving to each part of a picture its proper value of tone and color as these are modified by distance and by atmospheric conditions, the changes evident being from strong light and shade and positive colors in the foreground, to weak tones and neutral grays in the extreme distance. This branch of perspective can be mastered only by long study from Nature.

4. Middle visual ray, or "line of sight": This is the shortest straight line from the eye to the object.

5. Picture plane: This may be any plane between the eye and the object which is perpendicular to the middle visual ray. It is almost always assumed to be vertical; hence it corresponds to the vertical plane of projection.

6. Center of vision: This is the trace of the middle visual ray in the picture plane, as C. V., Figure 8.

7. Horizon: The natural horizon is the line in which the sky and an expanse of water or a level prairie would seem to meet. The pictorial horizon may be any horizontal line at the level of the observ-

er's eyes. Consequently, its projection in the picture plane will be a horizontal line passed through the center of vision. It may be imagined as the trace in the picture plane of a horizontal plane which passes through the eye, **H-H**, Figure 8.

The location of the horizon is of great importance. The level of the horizon changes according to the height of the eye. Thus, the observer may stand on low or on elevated ground, or be seated, and his horizon will be correspondingly low or high. The horizon must be so located as to cause the objects to appear natural—i. e., as we are accustomed to see them.

For an interior of an ordinary room, the horizon should be comparitively low, at an elevation of about four feet; otherwise the floor will appear to rise excessively as it recedes and the furniture will seem to be falling towards the observer. For the interior of a lofty room such as that of a church auditorium, or for a view of a street lined with tall buildings, the horizon should be placed higher, six or eight feet above the ground, or even more. Where the horizon is located much above the roofs of the buildings, the resulting picture is called a "bird's eye view."

8. Distance: In the top view and in the side view, the interval measured perpendicularly from the eye to the picture plane is termed "the distance." This should not be less than one and one-half times the greater dimension of the picture, Figure 8 (C. V. —S.=1½ times **a-b**).

9. Station point: For convenience, "the distance" may be assumed as in front of or as back of the picture plane, and in the top and the side views, may be set off from the center of vision. The point thus fixed is called "the station point," or point of sight. It is, in fact, the eye of the observer, **S**, Figure 8. At the station point, horizontal angles may be constructed geometrically—i. e., laid out in their true size, **S**, Figure 8.

10. Points of distance: These are points obtained by setting off the "distance" on the horizon to either or both sides of the center of vision. These points coincide with the vanishing points for horizontal lines which are at an angle of 45 degrees to the picture plane, **D, D**, Figure 8.

11. Vanishing points: In perspective, all parallel lines of the same set, if oblique to the picture plane, when produced, will meet in a point. This point is called their "vanishing point," as **Vr, Vl**, Figure 8. There will be always as many vanishing points as there are sets of parallels in the object which are oblique to the picture plane.

a. All horizontal lines inclined to the picture plane have their vanishing points in the horizon.

b. All lines oblique to both planes (V. and H.) have their vanishing points above or below the horizon.

c. If the horizontal lines are at an angle of 45 degrees to the picture plane, their vanishing points are in the points of distance.

d. If the lines are perpendicular to the picture plane, their vanishing point is in the center of vision.

12. Diagonal point or vanishing point of the diagonal: This is a point obtained by producing the bisector of any right angle until it meets the picture plane, **Dg**, Figure 8.

13. Measuring points: These points are used to determine the length of a line in perspective, **MR, ML**, Figure 8.

All lines which vanish in the right vanishing point (**Vr**) are measured by the "measuring point right"

(**MR**). Inasmuch as each vanishing point has its own measuring point, all lines vanishing in the left vanishing point (**Vl**) are measured by the "measuring point left" (**ML**).

14. Measuring line: A line on which true measures may be laid off. Any straight line in the picture plane may be used as a measuring line, provided it is in the same plane as the line which is to be measured.

15. Scope of vision: The area of a picture that can be seen without moving the head is the scope of vision. It forms the base of a cone having its vertex in the eye. Its vertex angle should not be greater than 40 degrees, **x-s-y**, Figure 8, otherwise objects near the limits of the picture will be distorted.

Rules.

1. At the station point, in the top view, all angles can be constructed geometrically. See Definition 9.

2. All lines parallel with the picture plane have no vanishing points; therefore, vertical lines are represented by verticals, and horizontal lines parallel with the picture plane are represented by horizontals.

3. All horizontal lines perpendicular to the picture plane vanish in the center of vision. They are measured by the points of distance.

4. Horizontal lines at an angle of 45 degrees to the picture plane vanish in the distance points; if at an angle of more or less than 45 degrees, they vanish in accidental points on the horizon.

5. The apparent size of an object diminishes as its distance from the eye or from the picture plane (P. Pl.) increases.

6. Parallel lines oblique to P. Pl. appear to converge as they recede, meeting in their vanishing point, if produced. For that reason:—

a. All lines of the same set of parallels have the same vanishing point; and

b. All lines having the same vanishing point are parallel.

7. If a straight line parallel with P. Pl. is divided equally, its divisions will appear equal. But if the line is oblique to P. Pl., these divisions will appear unequal, becoming shorter, apparently, as the line recedes.

8. Any plane figure such as a square, a circle, a hexagon, etc., if parallel with P. Pl., will appear in its true shape, but of its true size only when it coincides with P. Pl., diminishing in apparent size as it recedes, and increasing in apparent size as it advances therefrom. For this reason, true measures are laid off on the picture plane only.

9. The construction of the perspective of all objects in the same picture is governed by the established "distance."

10. All lines parallel with P. Pl. can be measured from any point in the horizon (parallels between parallels).

11. All lines which are oblique to P. Pl. can be measured from the measuring point that corresponds to the vanishing point of the respective lines.

12. In order that a picture may produce the correct illusion, it must be viewed from the proper distance. If "the distance" in a picture is three feet, the spectator should stand three feet from the picture, and directly opposite to the center of vision. If he should stand six feet away, the receding edges would seem to converge too much, and the representation would appear distorted. This is especially true of buildings, interiors, etc. See Definition 7.

13. The effect of size in a picture is produced by comparison. A building or a tree will appear large if some such object as a man, or a cow, drawn to a small scale, is placed nearby, because we unconsciously use these smaller objects as units of measure.

Problems.

As it is not intended that this little treatise shall be exhaustive, we will touch upon but the two most important methods of constructing perspectives.

The first, commonly called "the plan and elevation method," requires, as the name indicates, the plan and the elevation of the object, while the second method enables the draftsman to make his drawing directly from the statement of the dimensions of the object, just as he does in orthographic projection.

First Method—By Plan and Elevation.

This method is quite generally used by architects. It is very closely related to our orthographic projection.

Introductory Problem 1a—Figure 9.—To project a triangular pyramid, **A**, upon the picture plane, P. Pl., the height of the horizon, the distance, and the top and side views of the pyramid in its relation to P. Pl. being given, as shown in Figure 10, **A** and **B**.

Solution.—First, make a cabinet projection of the ground and of the P. Pl., Figure 9. Then locate points **c, a, b,** and **d**. Now, draw **c-c′, a-a′, b-b′**, etc., half their actual length, and construct the pyramid.

To construct the pyramid on P. Pl., Figure 9, pass a vertical cutting plane through the eye, S, and through angle **b′** of the pyramid. Then the line **b′-F** is the trace of that plane in the horizontal plane (the ground). The line **x-y** is the trace in P. Pl. Line **b′-S** is also an element of this cutting plane, and, intersecting the line **x-y** in the point **b′**, thus locates the angle **b′** of the pyramid in the picture plane. All other points are found in this same manner.

The following diagram, being a cabinet projection, does not give the correct perspective shape of the pyramid, but it illustrates the process of obtaining a true perspective by this method.

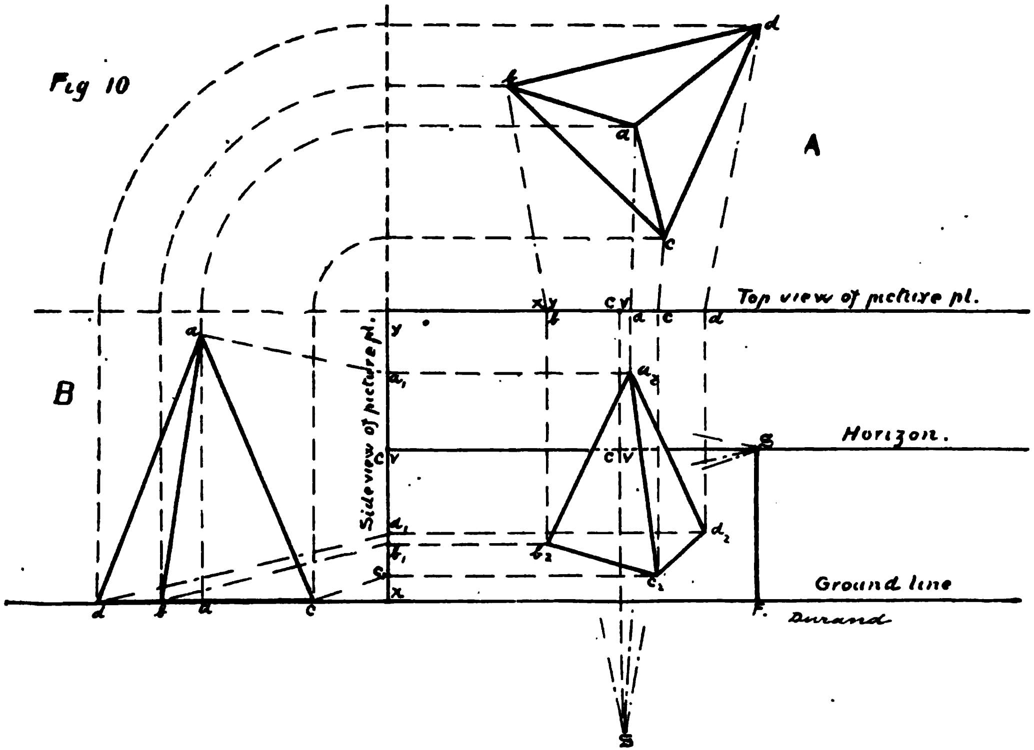
Introductory Problem 1b.—In this figure, Figure 10, the perspective view of the pyramid is derived from the top and the side views.

The top view, **A**, shows the traces of the cutting planes on the ground, and gives the apparent width in the top view of P. Pl., while the side view, **B**, gives the apparent heights in the side view of P. Pl.

Now, if we compare Figure 9 with Figure 10 closely, we shall find that the two figures are identical. To prove this, we will use the same wording to explain Figure 10 that we used to explain Figure 9.

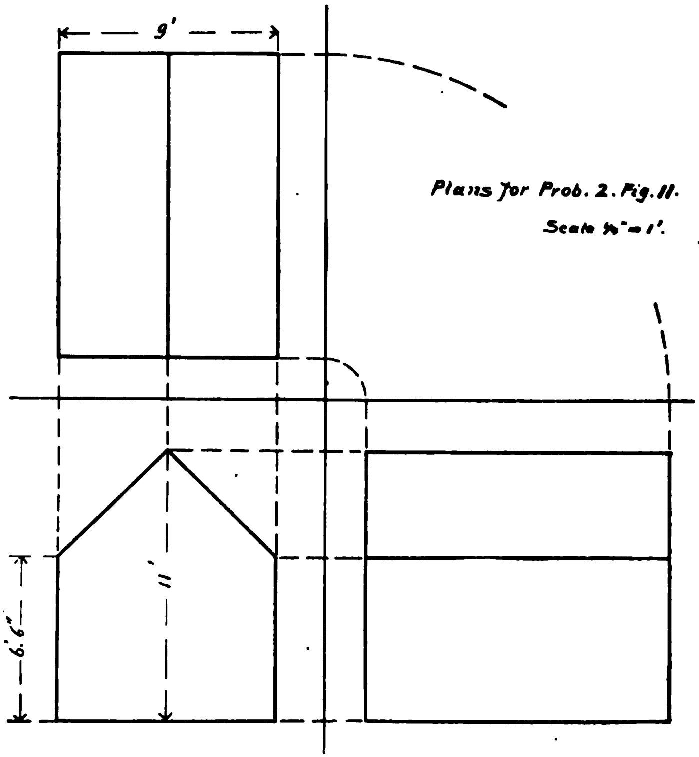
To construct the pyramid on the P. Pl., pass a vertical cutting plane through the station point, **S**, and through angle **b** of the pyramid. Then **b-x-F** is the trace of this cutting plane in the horizontal plane. The line **x-y** is the trace in P. Pl. The fact that P. Pl. is foreshortened to a straight line does not change the situation. Line **b-S** is also an element of this cutting plane, and, intersecting the line **x-y** in point **b′**, thereby locates the angle **b** of the pyramid in P. Pl., etc. In the top view, **S** and **F** coincide.

Fig 10


d
b
a
c
A
B
Top view of picture pl.
Side view of picture pl.
Horizon.
Ground line
S
Durand

Suggestion.—The perspective of a square prism or of some other similar object should be drawn by the method illustrated in Figure 10.

Note.—Most of the perspectives shown as illustrations in this work are not agreeable, because the "distance" assumed is too short. But if it were taken long enough, the points would fall without the page, which would render the illustrations less intelligible and the instruction less clear, because of reference to points that were not shown.



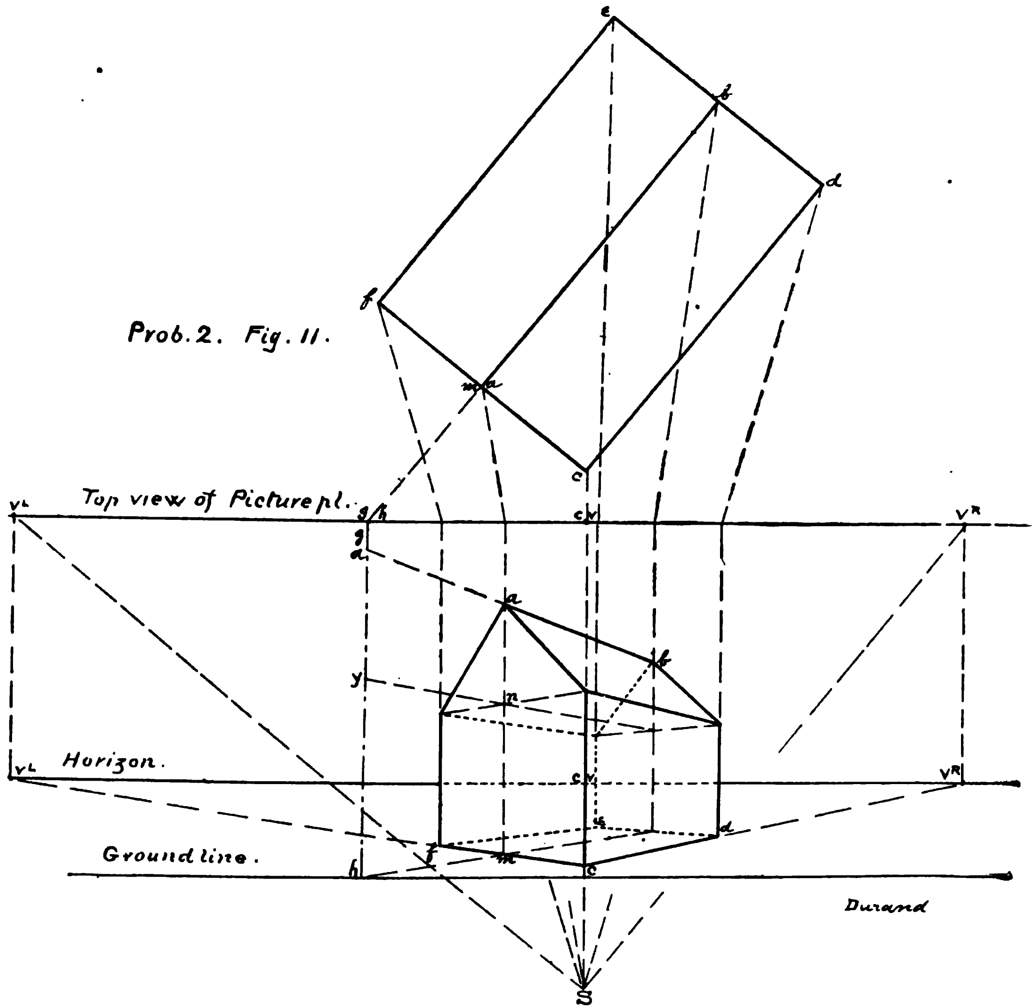
Problem 2.—To draw the perspective of a pentagonal prism resembling a cottage, as shown in the plan for Problem 2, Figure 11. Scale, ¼" to 1'. The front corner is to be located one or more feet back of P. Pl., the prism being in any oblique position, at the discretion of the teacher.

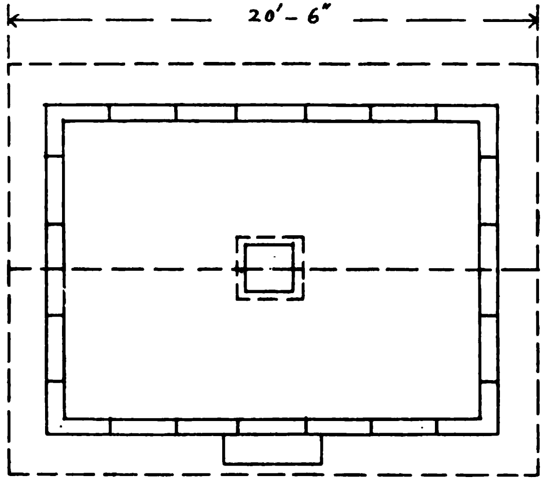
Solution.—Place the plan in the desired position, then lay off the distance C. V.-S., and find the vanishing points by drawing **S-Vr** and **S-Vl** parallel with the sides of the plan. **Vr** and **Vl** are the vanishing points respectively for the corresponding sets of parallels. See Rule 6 and the definition of Vanishing Points. Draw **a-S, c-S, d-S,** etc., until they pierce P. Pl. (Prob. 1). Locate the horizon 3' 3" above the ground, assuming the ground line at pleasure, and project the vanishing points to horizon—i. e., draw the front view of the picture plane.

To determine the different heights without the aid of the side view, pass a vertical cutting plane through the point, the elevation of which is to be established. The intersection of this plane with P. Pl. will be a vertical line on which true measures can be set off. These can be reduced to their perspective size by projecting to the vanishing point of the cutting plane. See Rule 8. To facilitate the work, this cutting plane coincides with one of the edges of the prism, the vanishing point of which is already established.

In Figure 11, this cutting plane was passed through **a-b**, cutting P. Pl. in **g-h**. In the perspective by drawing **i-Vr**, and **h-Vr**, **a-m** is found to be the perspective size of **i-h** (parallels between parallels are equal). Set off **h-y**, and draw a **y-Vr**, then draw **n-Vl** and **m-Vl**, also **c-Vr**, and **f-Vr**, etc. Further explanations seem unnecessary.

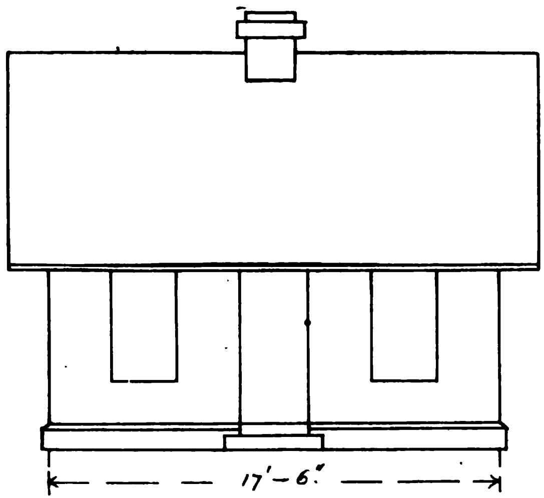
Prob. 2. Fig. 11.

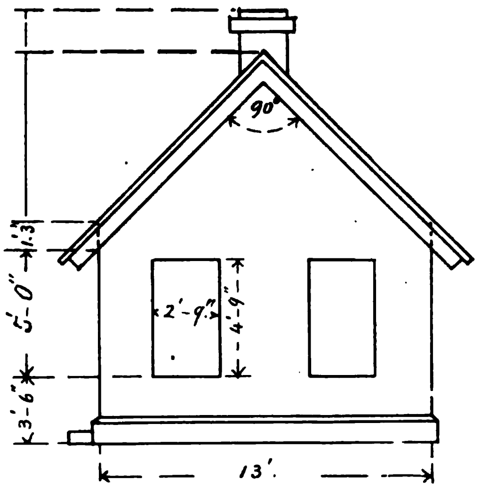


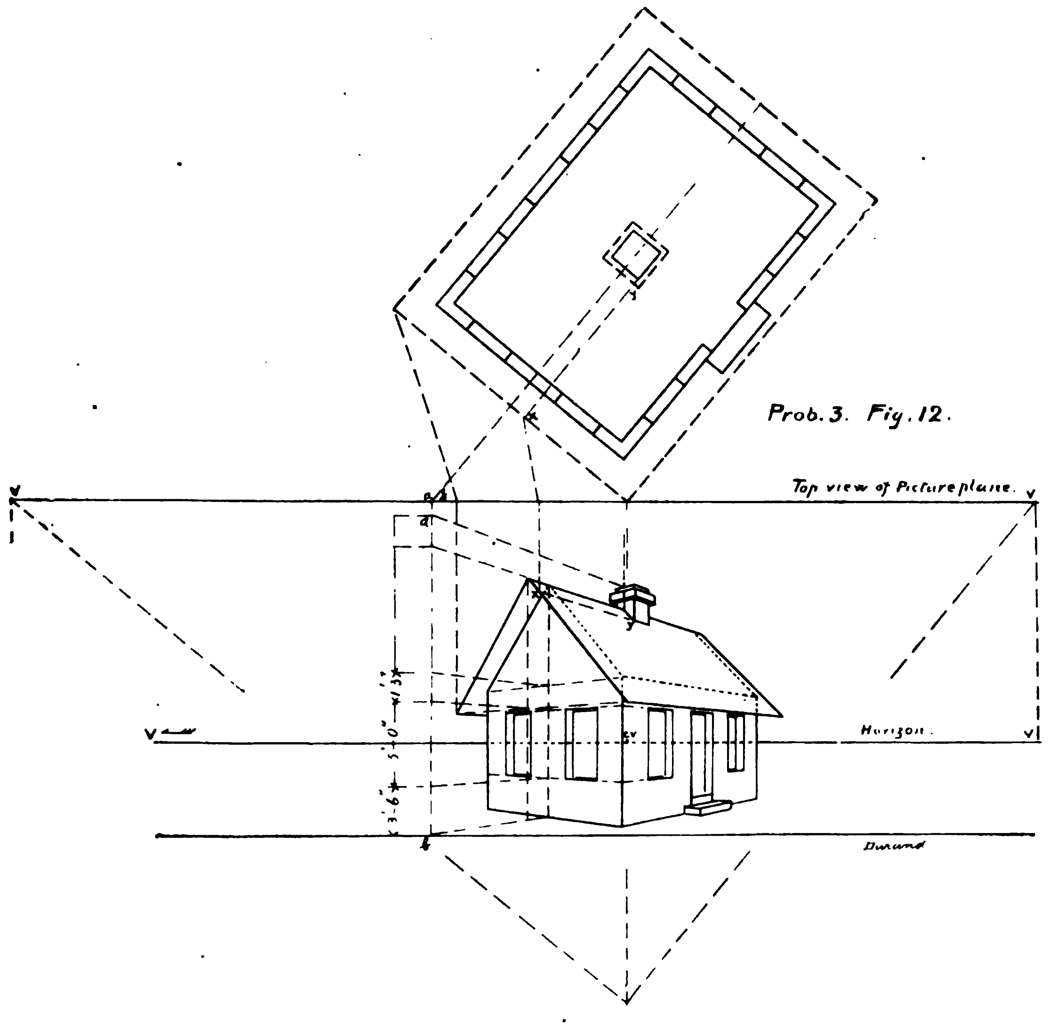


Plans for Prob. 3. Fig. 12.

Scale 3/16" = 1'.







Prob. 3. Fig. 12.

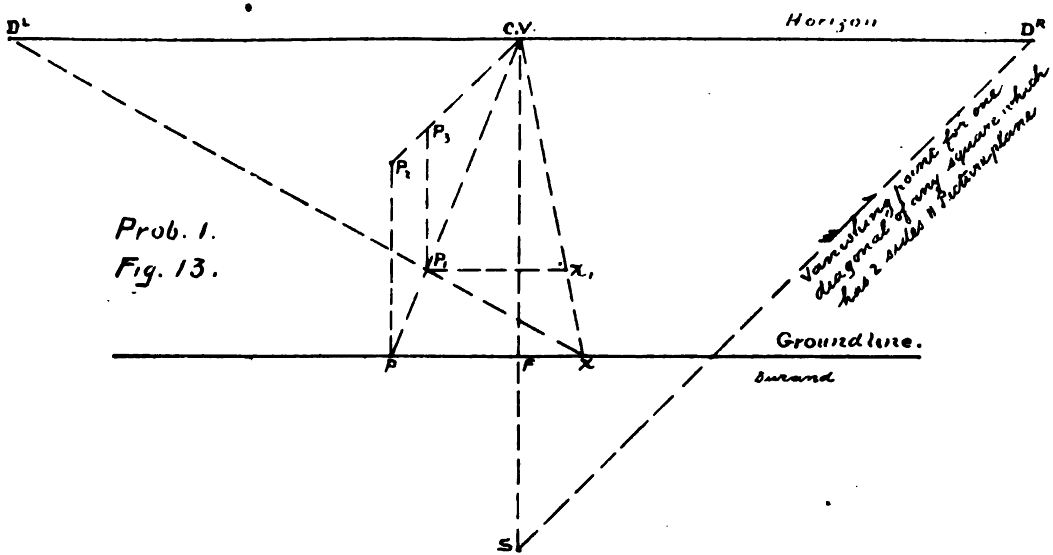
Problem 3, Figure 12.—To draw the perspective of a cottage from its plan and elevation.

Solution.—With the aid of two cutting planes, one of which is passed through the long axis of the building, and the other through the front lines of the roof, all points necessary for the construction of the perspective can be found, with the exception of the intersection of the chimney with the roof. To determine this, draw **x-y** in the plan and locate it in the perspective. As this problem is but a repetition of Problem 2, further help should not be given the student.

Suggestion.—The perspective of some other object should be drawn by the pupil in addition to this one, to familiarize him further with this method.

Second Method.

Problem 1, Figure 13.—Find the perspective of a point which is 2′ left of C. V., 3′ back of P. Pl., and 3′ above the ground. The distance is 8′. The horizon is 5′ above ground. Scale, ½″ to 1′.



Prob. 1.
Fig. 13.

Solution.—Place the point, **P**, 2″ left on the ground line, then draw line **P-C. V.** parallel with **F-C. V.**, (Rule 6a). Lay off **P-x** equal to 3′, and draw **x-Dl.** Then **P-P′** equals **P-x**, and **P′** is 3′ back of P. Pl.

Proof.—**x-P′** is a diagonal (parallel with **F-Dl**), and **P-P′** is one of the sides of the square, **P-x-x′-P′**. At **P** and **P′** erect perpendiculars, and lay off **P-P²** equal to 3′; draw **P²-C. V.** Then **P-P³** equals **P-P²**, equals 3′ (parallels between parallels), and **P³** is the required perspective of the given point.

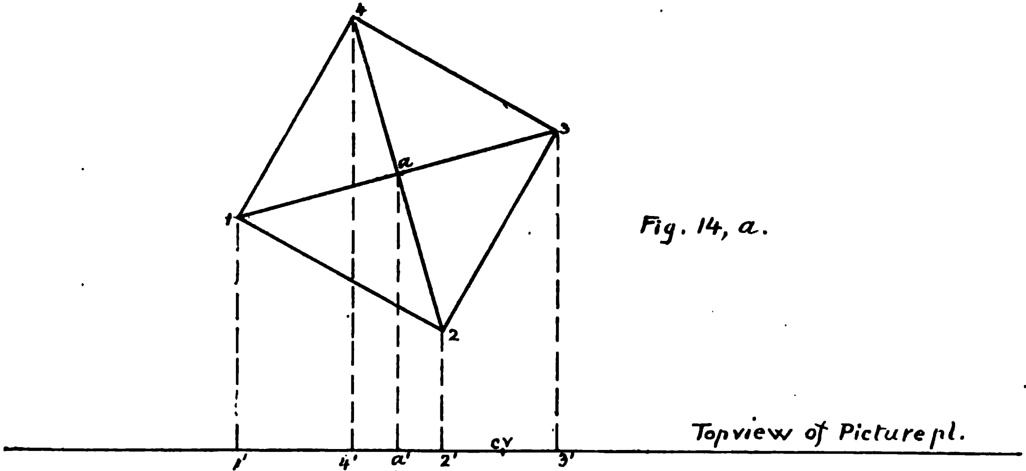


Fig. 14, a.

Prob. 2.

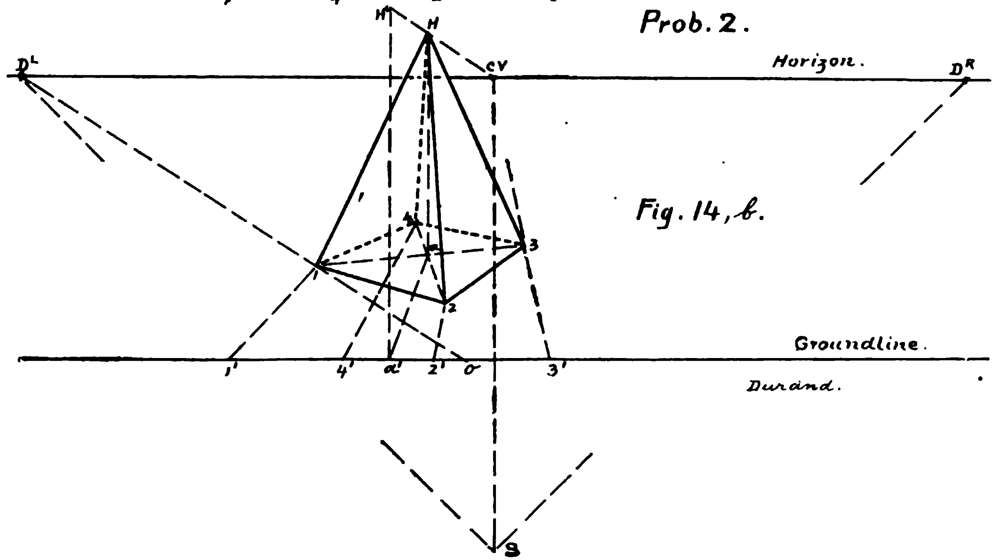


Fig. 14, b.

Problem 2.—Construct the perspective of a pyramid. The pyramid is 4′ square and 6′ high. Two sides of the base, which is on the ground, are inclined 30 degrees L. to P. Pl. The front corner is 1′ left of C. V. and 2′ back to P. Pl. The horizon and the distance are the same as in Problem 1. Scale, ½″ to 1′.

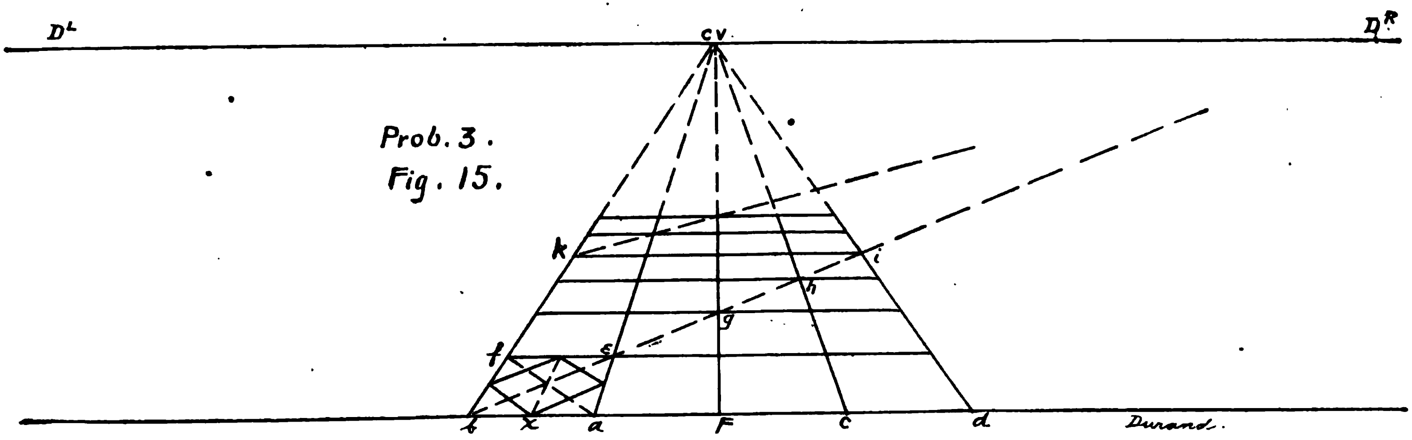
Solution.—Draw the top view of the pyramid in the position specified, as shown in Figure 14; then place points **1, 2, 3, 4, A**, and **H** by the method used in Problem 1. For example, take distance **CV-1′**, Figure 14a, and set off on the ground line, Figure 14b. Draw **1′-C. V.** Then set off **1′-O** equal **1-1′**, Figure 14a, and draw **o-D**, etc.

To prove the accuracy of the position of point **a** in the base of the perspective, the diagonals may be drawn.

Suggestion.—The teacher should give the pupil one or two other simple problems to be solved by this method.

Problem 3, Figure 15.—To construct a perspective of any number of squares. The squares are 2′ on a side, and two sides of each square are parallel with P. Pl. The horizon is 6′ above ground. The distance is 12′ 6″. The C. V. is in the middle of the picture. Scale, ½″ to 1′.

Solution.—Make **F-a, a-b, F-e**, and **c-d**, equal to 2′. Draw **a-C. V., b-C. V.**, etc. These lines are perpendicular P. Pl. (Rule 3). Draw **b-Dr.** Then, **b-e** is a diagonal square of **b-a-e-f**, inasmuch as **b-D** is at an angle of 45 degrees to P. Pl.—i. e., 45 degrees to **b-a.** A line parallel with P. Pl. drawn through point **e** will give the first row of squares. The line **e-g** fixes the depth of the next row, etc. Another line drawn from **k** will give four more rows of squares. This process may be continued until all the space to C. V. is subdivided. By drawing both the diagonals and the line **x-C. V.**, through their point of intersection, another



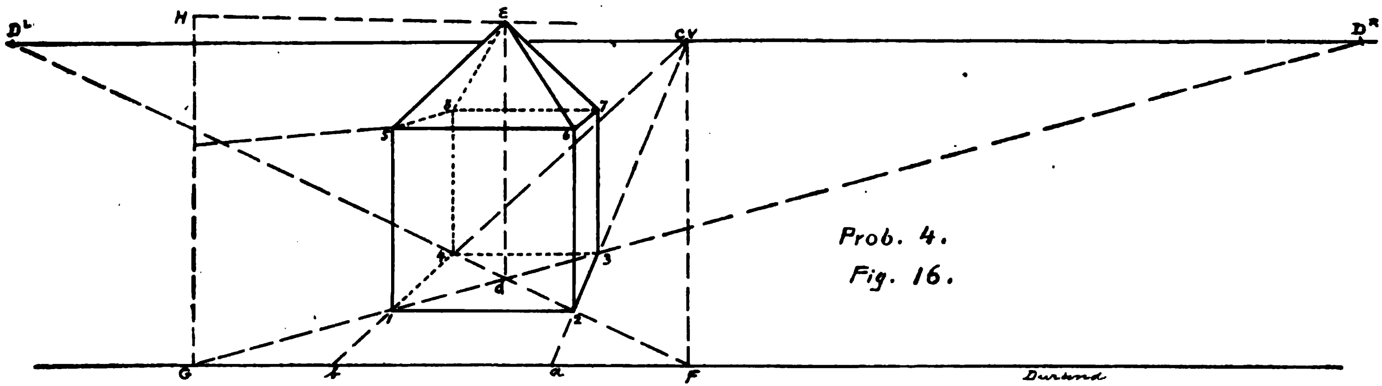
set of squares may be constructed the pairs of the sides of which will converge respectively at **Dr** and at **Dl**.

Problem 4, Figure 16.—To construct the perspective of a cube upon which is a square pyramid.

The length of an edge of the cube is 4′. The altitude of the pyramid is 2′, and its base coincides with the top of the cube. Two faces of the cube are parallel with P. Pl. Its right, front, vertical edge is 2′ 6″

2-6′ each equal to 1-2. Draw 5-C. V. and 6-C. V., join 7 and 8, and so finish the cube.

To find the vertex of the pyramid, point **e**, pass a plane through points **d**, **e**, and **Dr**. Then **D-G** and **G-H** are the traces of this plane on the ground and in P. Pl., respectively. Make **G-H** equal to the height of the cube plus the height of the pyramid—i. e., 6′ (Rule 8). Draw **H-Dr**, making **d-e** equal to **G-H** (parallels between parallels). Draw **e-5**, **e-6**, etc., and the problem is completed.



Prob. 4.
Fig. 16.

L. of C. V. and 2′ 6″ back of P. Pl. The horizon has an elevation of 6′, the distance is 12′ 6″. Scale, ½″ to 1′.

Solution.—Locate the point **2** by the method used in Problem 1. Make **a-b** equal to 4′, and draw **b-C. V.** Then **2-1** equals **a-b**, equals 4′ (parallels between parallels). Draw **1-D**, making **2-3** equal to **1-2** (Problem 1), and complete the square **1-2-3-4**. Erect perpendiculars at the points **1, 2, 3,** and **4,** making **1-5′** and

Problem 5, Figure 17.—To draw the perspective of a line of a given measure which is oblique to the picture plane.

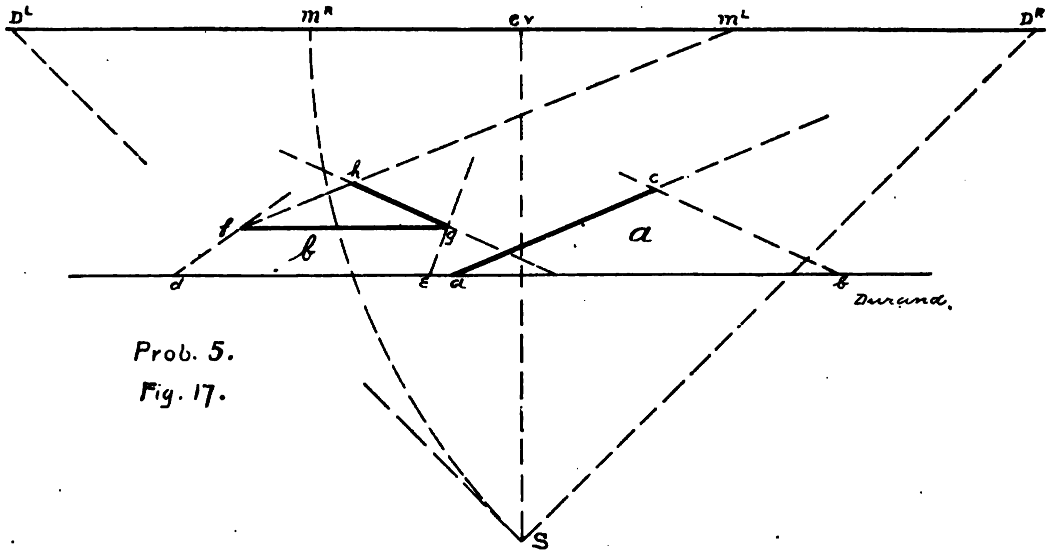
a. The nearer end of the line to lie in the ground line, and **Dr** to be its vanishing point. Length, 6′. Scale, ½″ to 1′.

b. The nearer end of the line to be 2′ back of P. Pl. and 1′ 4″ L. of C. V.; **Dl** to be the vanishing point. Length, 4′. Scale, ½″ to 1′.

Solution.—Locate the horizon, the ground line, C. V., the distance points and the station point.

a. Make **Mr.-Dr.** equal to **Dr.-S**, and draw **S-Mr.** Then **Mr.** is the measuring point for **Dr.** (Definition 13). **Ml** is found in the same way as **Dl.** Draw line

b. Locate **g** as explained in Problem 1, and make **f-g** equal to **d-e** by drawing **d-C. V.** (parallels between parallels), then proceed as in Problem 5a. Length **d-e**, first had to be reduced to the perspective length **f-g** before **g-h** could be measured, because **g** is 1′ back



Prob. 5.
Fig. 17.

a-c towards **Dr.** from **a** in the ground line, and lay off **a-b**, equals 6′. From **b** draw **b-Mr.**, intersecting **a-c** in **c.** Then **a-c** equals **a-b**, equals 6′

Proof.—Triangle **a-b-c** is similar to triangle **Mr.-Dr.-S**, because:

a-b is parallel with **Mr.-Dr.**

a-c is parallel with **S-Dr.** because they have the same vanishing point (Rule 6).

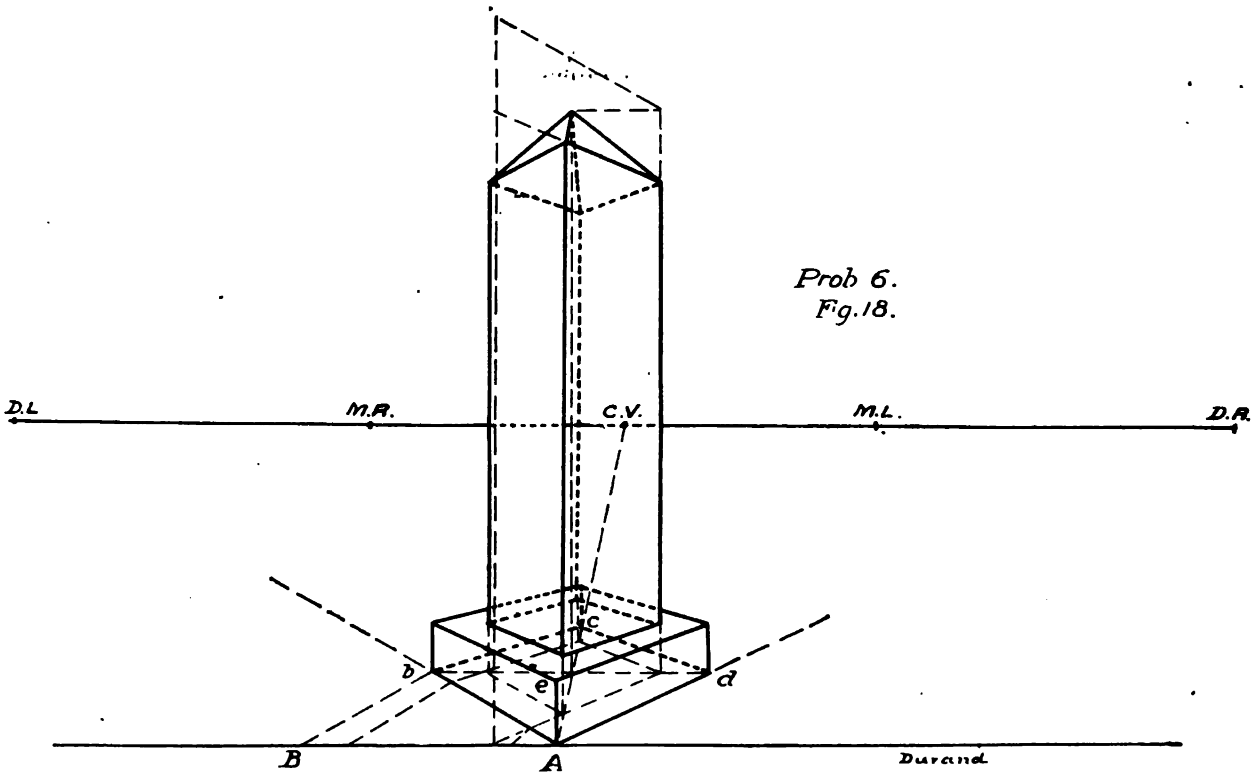
b-c is parallel with **Mr.-S** because they have the same vanishing point.

S-Dr. equals **Mr.-Dr.**, consequently **a-c** equals **a-b.**

of P. Pl. There is another method of finding the length of **g-h** which will be explained in Problem 7.

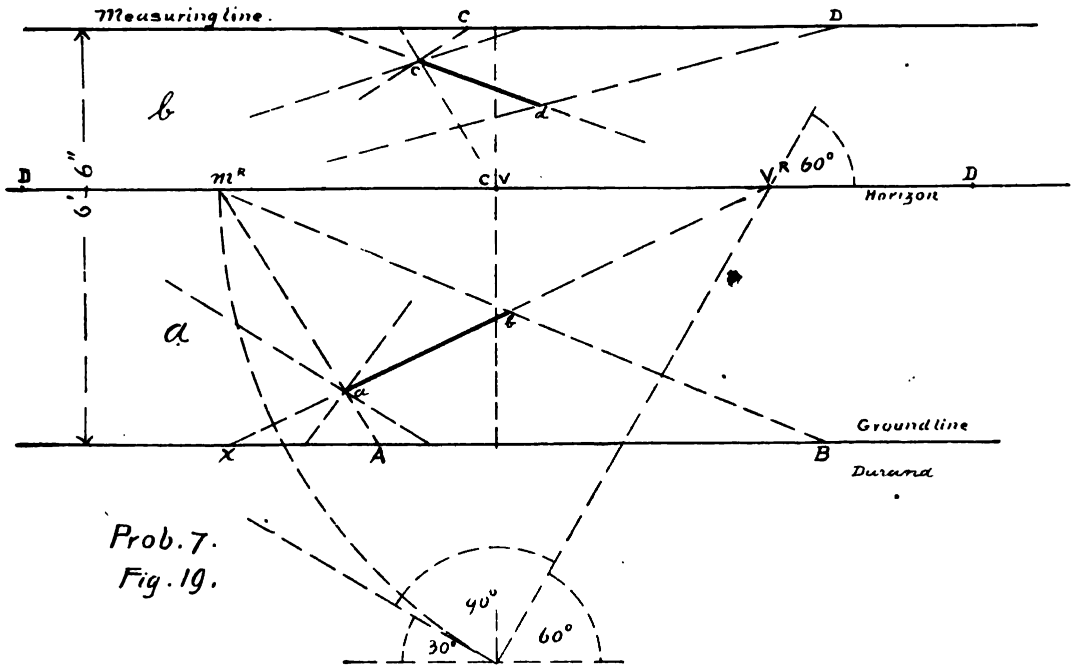
Problem 6, Figure 18.—To draw the perspective of a rectangular monument.

The object comprises a square plinth 4′ on a side and 1′ thick, so placed that one of its diagonals is perpendicular to P. Pl. The nearest corner is 1′ L. of C. V., and in P. Pl. On top of this plinth is a prism 2′ 6″ square and 9′ high, terminating in a pyramid having an altitude of 1′ 6″. All parts of the object are centered on the same vertical axis.



Solution.—Locate point **A** as in Problem 1. Draw lines **A-Dr,** and **A-Dl,** inasmuch as the points of distance are the vanishing points for the sides of the square. The C. V. is the vanishing point for the retreating diagonal which is perpendicular to P. Pl. and is so drawn. Make **A-b** equal to **A-B**, equal 4′, by the process explained in Problem 5. Draw **b-c** until it intersects line **A-C. V.**, which represents the diagonal of the base. Then draw **c-d** and **c-b**, thus completing the figure. Next, erect perpendiculars at **A, b, c,** and **d.** Make edge **A-e** equal to 1′. Construct a perspective of the top, and complete the plinth.

To construct the prism, it is best to draw its plan on the ground, and therefrom, to project up. For complex constructions it is still better to construct all plans a few feet below the ground to avoid confusion of lines.



Prob. 7.
Fig. 19.

Problem 7, Figure 19.—To find a perspective of a line of a given length which is oblique to the picture plane; second method.

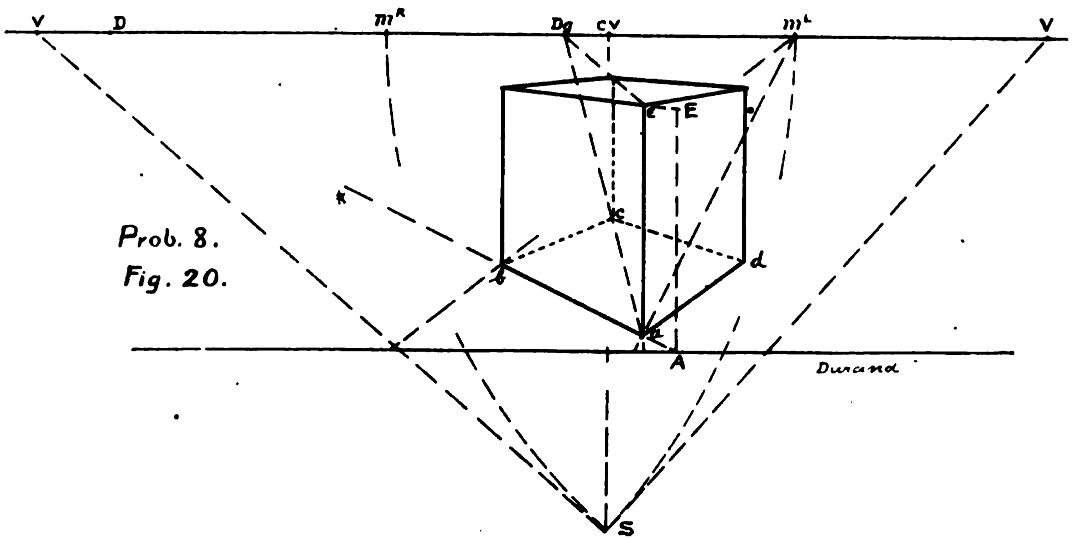
a. The nearer end of the line **a-b** is 3′ L. of **C. V.**, and 2′ back of P. Pl. Its length is 7′. It is inclined at 60 degrees R. to P. Pl. Scale, ½″ to 1′.

b. The nearer end of the line **c-d** is 1′ 6″ L. of the C. V., and 2′ back of P. Pl. The line is horizontal, is 6′ 6″ above ground, and vanishes in **Vr.** Its length is 7′. Given, horizon 4′ above ground; distance 7′ 6″.

Solution a.—Locate point **a** as in Problem 1. Find **A** by drawing a straight line from **Mr.** through **a** to P. Pl. Lay off **A-B** equal to 7′, and draw **B-Mr.**, cutting **a-Vr.** in point **b**; then **a-b** equals **A-B**, equals 7′.

Proof.—**x-b** equals **x-B** (proof, Prob. 5a), and **A-Mr.** is parallel with **B-Mr.**; consequently, **a-b** equals **A-B**, equals 7′.

Solution b.—Locate a measuring line (Definition 14) 6′ 6″ above the ground line (Rule 8), then proceed as in Prob. 7a.



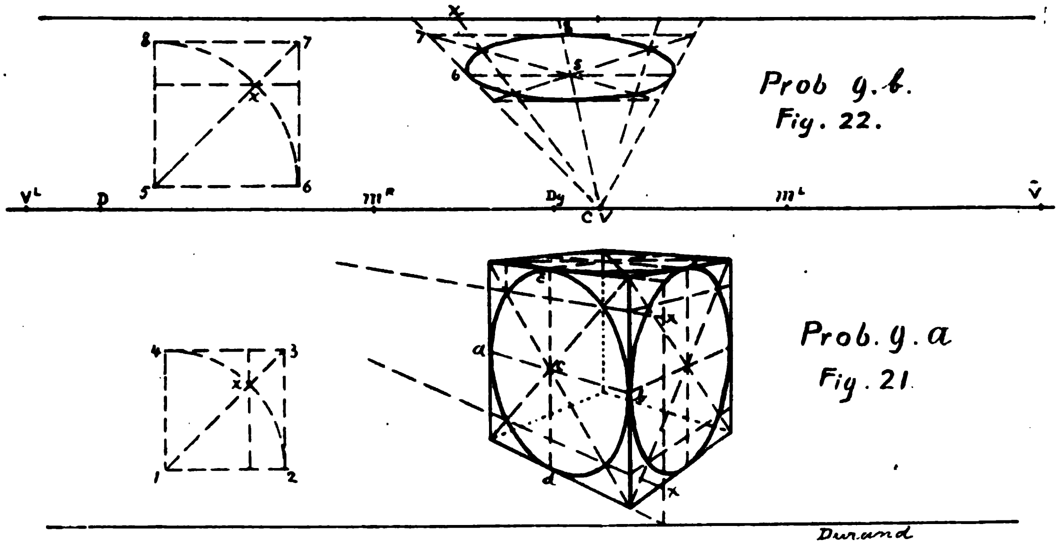
Problem 8, Figure 20.—To construct the perspective of a cube having its vertical faces unequally oblique to the picture plane.

The axis of the cube is vertical. Its front vertical edge is 6″ back of P. Pl., and to the right or left of C. V. Length of an edge is 3′ 6″. Scale, ½″ to 1′.

Solution.—At the station point construct the top view of the front angle of the cube in the desired position, and find the necessary vanishing, distance, and measuring points on the horizon.

Locate **a** and find the length of **a-b**; then draw **b-c**, and locate **c** by drawing the diagonal **a-Dg**. Lay off **A-E** equal to 3′ 9″, and find **a-e** (Rule 10). The rest needs no explanation.

Following Prob. 8, a practice problem should be drawn, such as a simple building, a monument, or some similar object.



Problem 9, Figures 21 and 22.—Draw the same cube given in Prob. 8, and construct:

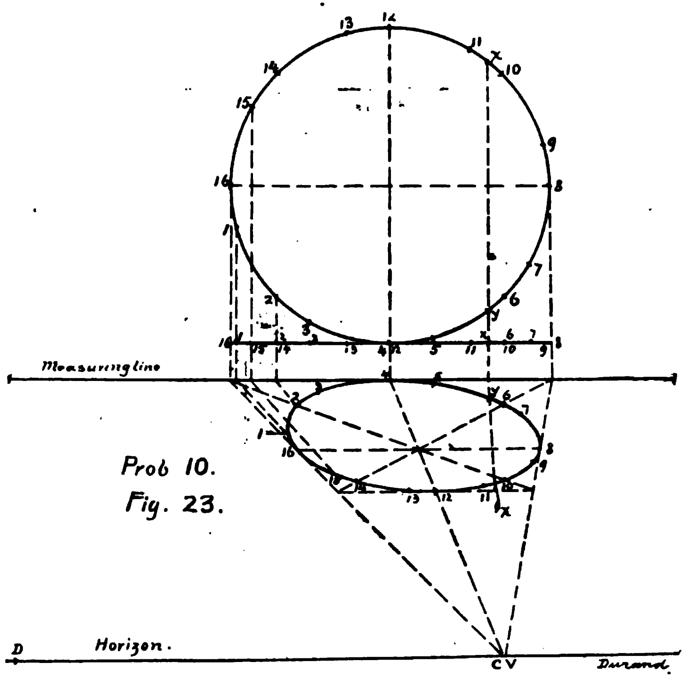
a. The perspective of a tangential circle on each of the three visible faces of the cube.

b. The perspective of a horizontal circle 8′ above the ground, the center of the circle to be 3′ back of P. Pl. Diameter, 4′ 6″.

Solution a.—Draw the diagonals of each side of the cube to find its center, as **c**. Through **c** draw the vertical and horizontal axes **a-b** and **d-e**, thus establishing four points of the ellipse **a**, **b**, **d**, and **e**. Draw a quadrant of the circle included in the square **1**, **2**, **3**, **4**; draw diagonal **1-3**, and then find **x** on the diagonals of the faces of the cube.

Solution b.—Locate a horizontal measuring line 8′ above the ground, as shown in Prob. 7.

As the circumference of a circle has no vanishing points, it may be constructed by the aid of C. V. as well as by the aid of any other vanishing points, as illustrated in Fig. 14b.



Problem 10, Fig. 23.—To divide the perspective of the circumference of a circle into any number of equal or unequal parts.

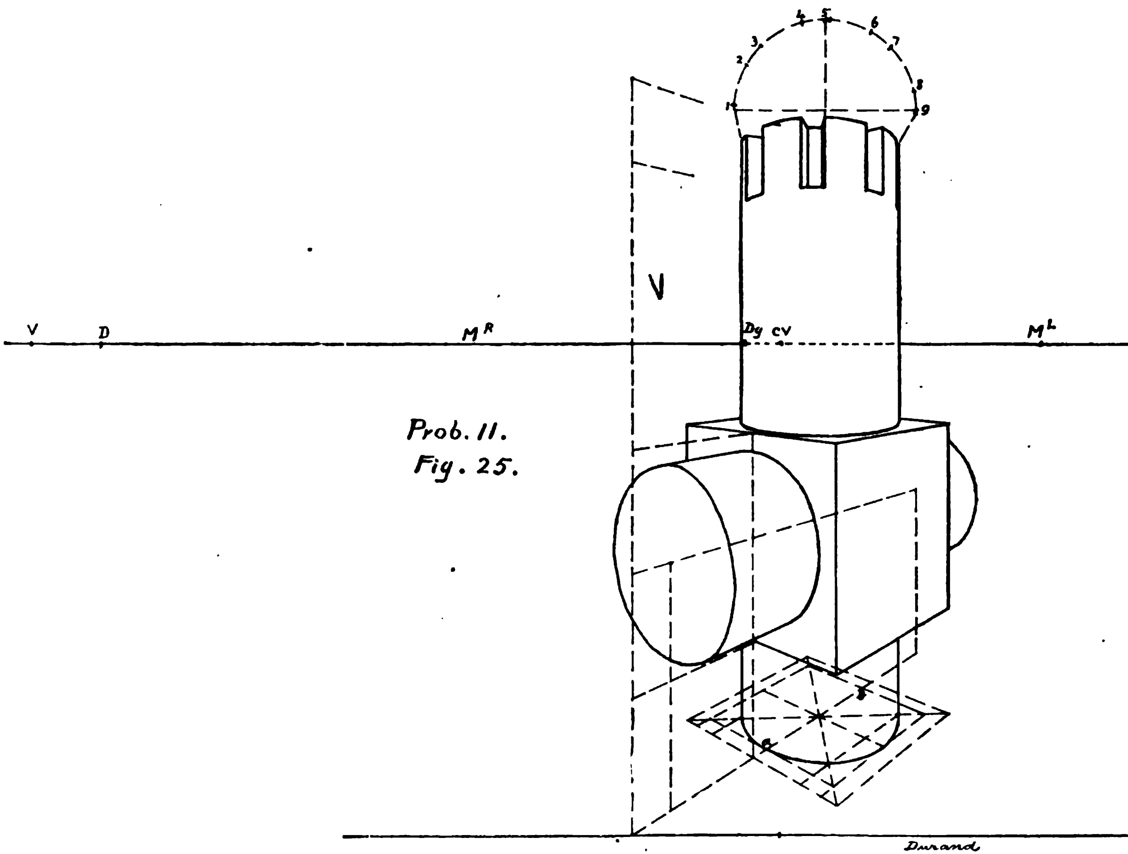
Solution.—Draw the front and top view of the circle and its horizontal perspective, as shown in Prob. 9b.

Locate the desired points on the front view, and project these to the top view; then locate the points on the perspective of the circle by projecting in the direction of C. V., the vanishing point from which the perspective was constructed.

If any more than eight points for the construction of the perspective of the circle should be wanted, any point in the circumference, as **x**, **y**, etc., Fig. 23, may be located by the "Second Method," Prob. 1.

Problem 11, Figs. 24 and 25.—Construct the perspective of the following combination; a cube penetrated by two circular cylinders, in accordance with the accompanying sketch and description.

The edges of the cube are 2½" long, and one set of them is vertical. Its vertical sides are unequally



Prob. 11.
Fig. 25.

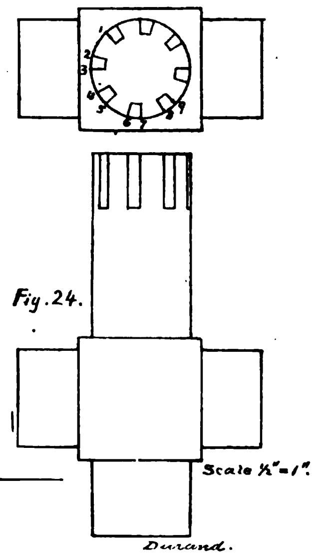
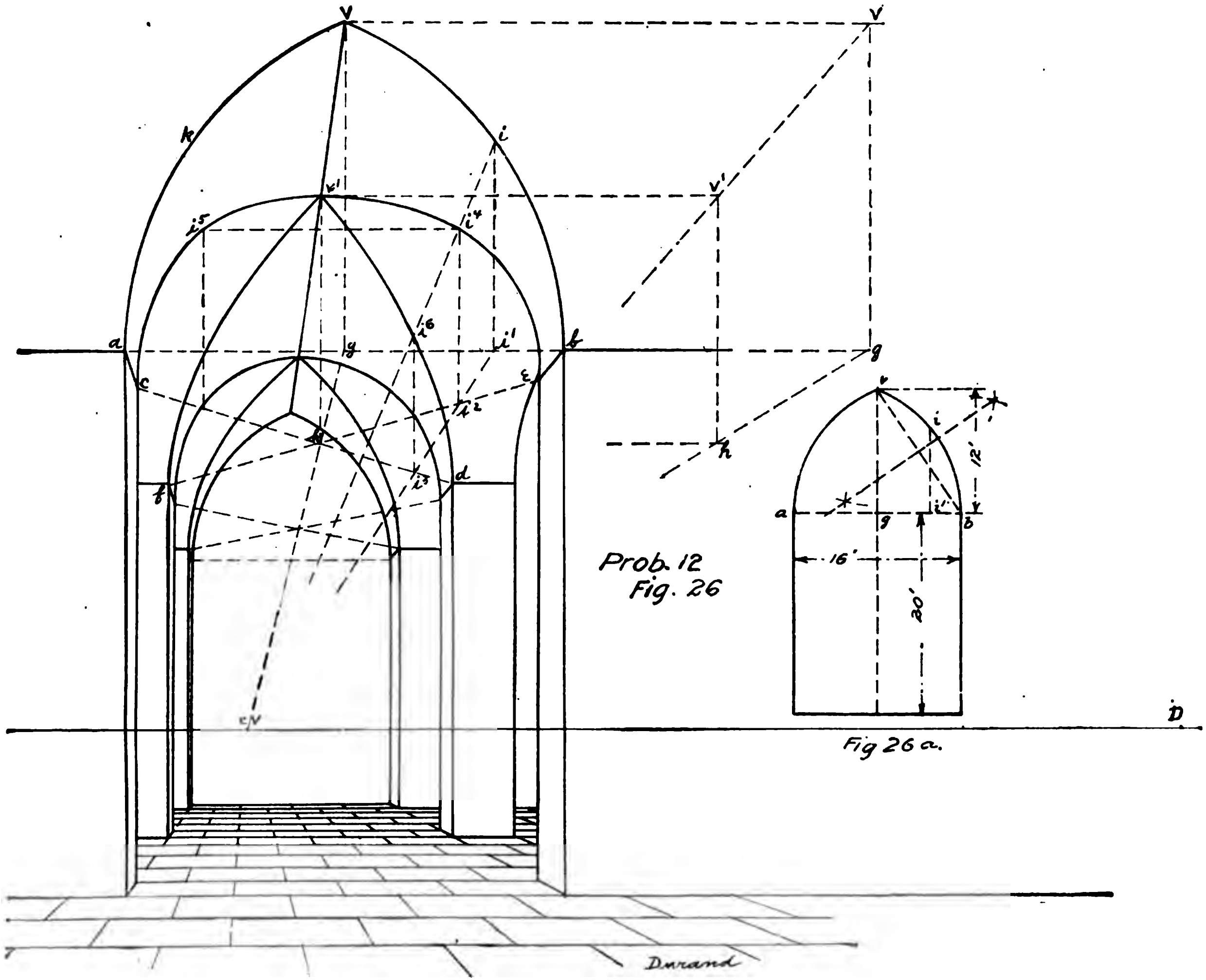


Fig. 24.

oblique to P. Pl. The axes of the cylinders coincide respectively, one with the vertical and the other with a horizontal axis of the cube. The length of the horizontal cylinder is 5"; its diameter is 1⅞", and its axis is centered at the vertical axis of the cube. The length of the vertical cylinder is 7"; its diameter is 3¾", and its axis is centered ½" below its intersection with the top face of the cube.



Prob. 12
Fig. 26

Fig 26 a.

Problem 12, Fig. 26.—To construct the perspective of a cloister (an arched walk), the ceiling of which is a groined Gothic vault.

Assume the columns to be 3′ square and 20′ high, and the vault to have a rise of 12′ and a span of 16′. The construction of the Gothic arch is shown in Fig. 26a.

Solution.—After constructing the arch **a-v-b** on P. Pl., draw **v-C. V.** The vertices of all arches will be in this line, for these vertices are all at the same level, and all are in the horizontal line perpendicular to P. Pl. of which **v-C. V.** is the perspective. Draw **b-C. V.**, and mark off the width of the columns, **b-e** and **a-c**, equals 3′, making **e-d** and **c-f** each equal to **a-b**. Now, draw **c-d** and **e-f**, which lines represent the perspective of the ground plan of the vault, **h** representing its vertex. A perpendicular from the point **h** intersecting **v-C. V.** in **v′**, will locate the perspective of the actual vertex of the vault. If the intersection of **h-v′** with **v-C. V.** should be too inexact, the construction may be made further to the right or to the left of C. V., the point so found being then projected directly over to **v-C. V.**

To construct the curve of the groin of the vault, points, as **i**, must be assumed in the arch **v-b** and the perspective of a horizontal line perpendicular to P. Pl. through them must be used to determine the perspectives of the corresponding points in the groins. To do this get the perspective of the plan of **i-C. V.** in the plane of the perspective of the plan of the groins. This is **i′-C. V.** The intersection of this line with **c-d** and **e-f** in points i^2 and i^3, establish the location of the points in the perspective of the groin. By projecting upwards, the perspective of the actual points in the groin may be found in line **i-C. V.** The curve of the groins will then pass from **v′** through these points to **e** and **d** respectively.

Now, carry **i** across to **v-a** in point **k**, and draw **k-C. V.** In like manner project i^4 straight over to **k-C. V.** in point i^5, these two points being in a plane parallel with P. Pl.

It should be plain that the construction of this perspective is simply an application of the second method, Problem 1.

In Figure 26 the method of finding one point in the curve of the groin is shown. By this same process other necessary points were found, and at least three should be found by the student in constructing the problem.

In combination with Problem 12, Fig. 26, the construction of approximate eliptical and true eliptical arches with their points may be given.

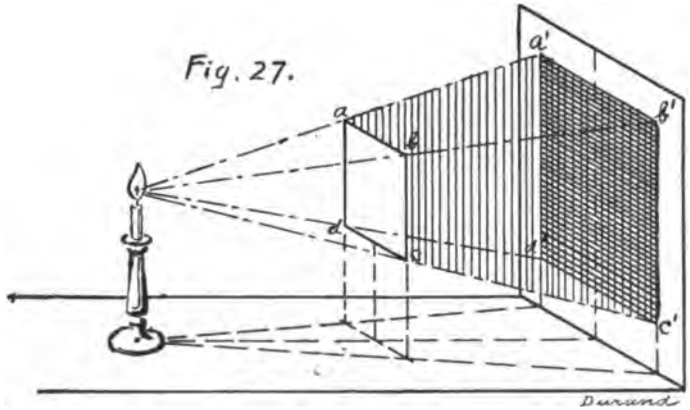
The student also may display his skill in free-hand drawing by executing the figure with columns in the style of the Gothic order, having appropriate capitals, bases, and ornamental details.

The Perspective of Shadows.

If rays of light from any source are intercepted by an opaque body, the portion of space back of the object from which the light is cut off, is said to be "in shadow." See Shadow Projections.

If the rays of light come from the sun, this shadow space is a cylinder (prism) in form, because, so great is the distance of the sun that the rays are practically parallel; if sent out from an artificial source, this shadow space is a cone (pyramid) in form, because the rays from such a source of light radiate in all directions from that one point.

Fig. 27.



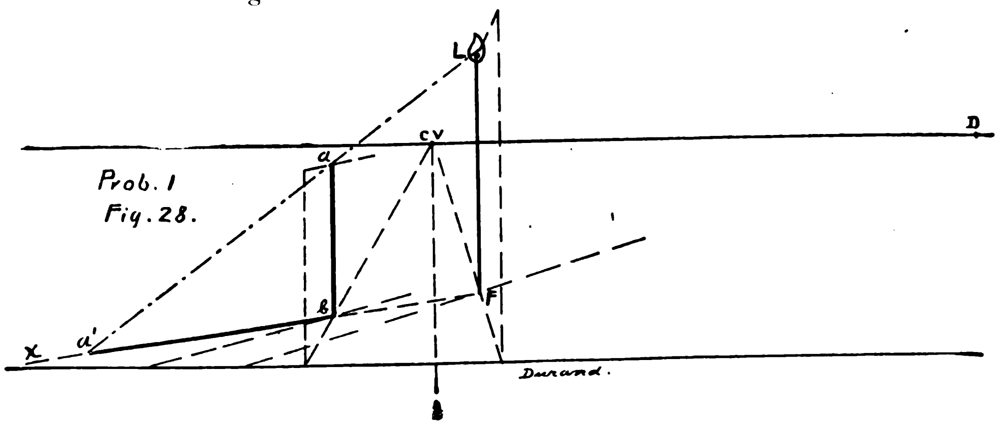
The shadow space so formed, called 'the umbra,' is not visible, but if intercepted by any surface, that part of the intercepting surface which is included within the trace of the umbra (cylinder or cone), will be dark, and consequently can be distinguished from the lighted portion of the surface. In Fig. 27, **a′-b′-c′-d′** is the visible or cast shadow of the figure **a-b-c-d.**

Shadows by Artificial Light.

Problems.

Problem 1.—Given the source of light 1′ R. of C. V., 4′ back of P. Pl., and 5′ 6″ high. Horizon 3′ 6″ above ground.

Prob. 1
Fig. 28.



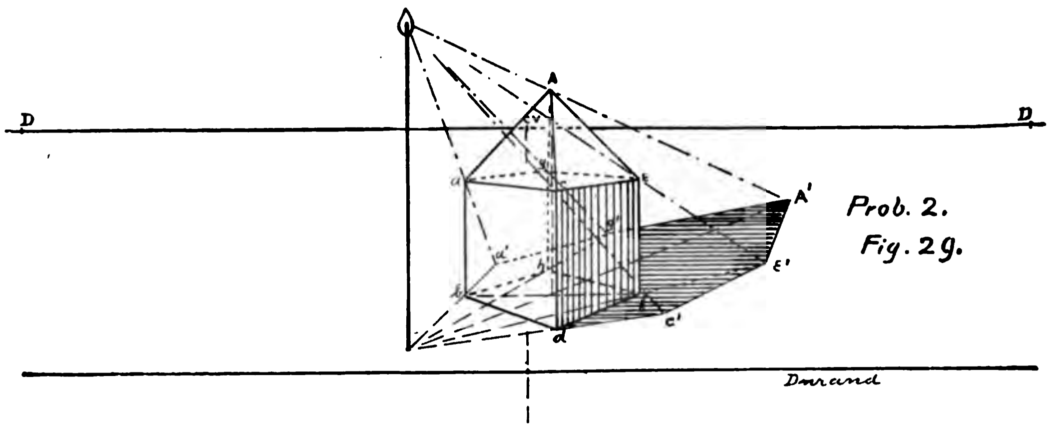
a. Cast the shadow of a vertical line 3′ high, which is placed 2′ L. of C. V. and 2′ 6″ back of P. Pl. Scale, ½″ to 1′.

b. From the same source of light cast the shadows of three or four vertical lines of any length, and placed wherever the teacher or student may decide.

Solution.—The shadow of **b**, Fig. 28, coincides with the point **b** itself. To locate the shadow of **a** we must draw a ray from **L** through **a**, and extending it, find its trace in the ground. But, to determine this point we need to pass a plane through **L-F** and **a-b** (parallels), and to find its trace on the ground, the line **F-b-x**. Now, since **a-L** and **b-F** are elements of this same plane, **a′** is the point where **a-L** strikes the ground, and represents the shadow of **a**. The shadow of line **a-b** is **a′-b′**.

Problem 2.—Cast the shadow of the cube and pyramid, as illustrated in Fig. 29.

Solutions.—Cast the shadows of lines **a-b**, **c-d**, **e-f**, and **g-h**, for the cube, then cast the shadow of the axis, **A-B**, and by connecting the respective points in their order in the line of shade, the problem will be finished.



Prob. 2.
Fig. 29.

Problem 3, Fig. 30.—Given the perspective of the interior of a prism (room) 16′ wide, 12′ deep, and 13′ high. Horizon, 5′ 6″ high. Source of light, 2′ R. of C. V., 2′ 6″ back of P. Pl., and 8′ above the base (floor). Scale, ½″ to 1′.

Cast the shadows of a set of lines which are perpendicular to the different sides of the prism respectively, each of these lines to be 4′ long.

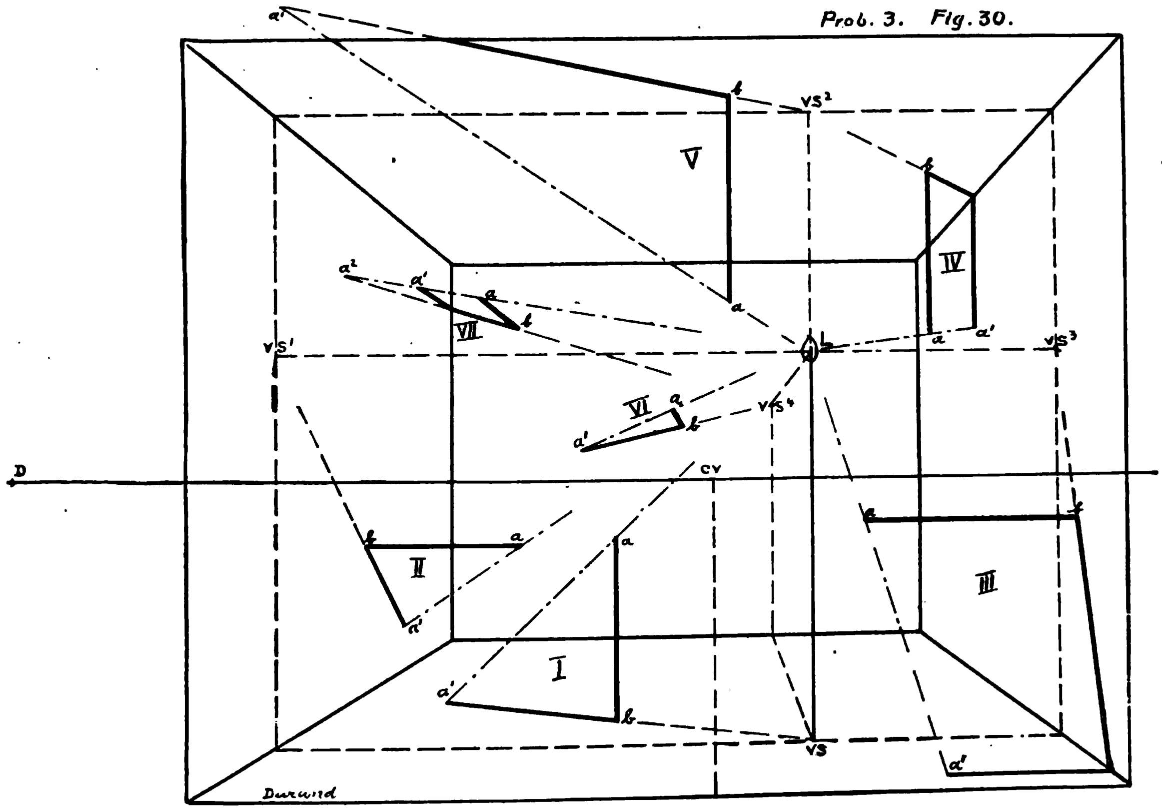
Placing: Line I—2′ R., 4′ back of P. Pl.
Line II—3′ 9″ up, 6′ back of P. Pl.
Line III—4′ 6″ up, 1′ 6″ back of P. Pl.
Line IV—5′ 3″ R., 5′ back of P. Pl.
Line V—6″ R., 1′ 6″ back of P. Pl.
Line VI—1′ L., 7′ 3″ up.
Line VII—6′ 6″ L., 10′ 6″ up.

Note the difference in the apparent lengths of the lines.

Solution.—From Prob. 1 we learn that **F**, the foot of the light, is the vanishing point for the shadows of all lines perpendicular to the ground. For this reason we shall, hereafter, call this point, V. S., vanishnig point of shadows.

Now if we drop perpendiculars from **L** to the other planes of the prism, we obtain points which will have the same functions for the respective planes that V. S. has for the ground—i. e., they will be vanishing points for the shadows of all straight lines which are perpendicular to those several planes. See, V. S., V. S.[1], V. S.[2], V. S.[3], and V. S.[4], in Fig. 30.

Prob. 3. Fig. 30.



I. in Fig. 30 is the same as the vertical in Prob. 1, Fig. 28.

II. in Fig. 30 is the same as I., excepting the difference in position.

III. in Fig. 30 is the same as I and II with the exception that the shadow falls partly on the side plane and partly on the horizontal plane. The shadow on the horizontal plane is parallel with line **a-b**, because the plane is parallel with **a-b**. The shadow of point **a** is located in the same way as was the like point in Prob. 1.

IV. in Fig. 30 is the same as III.

In V., which is the same as I., the shadow of **a** falls outside of our drawing.

VI. is the same as I.

VII. is the same as III., with the exception that the shadow on the side plane is directed towards C. V.; **a-b** being perpendicular to P. Pl., $\mathbf{a}^2$ would be the shadow of **a**, were the side vertical removed and the rear plane produced.

After a careful study of Prob. 3, Fig. 30, the student should be able to solve almost any problem in this subject.

Problem 4, Fig. 31.—The perspectives of the shadows cast by the furnishings of a room, give a practical application of Prob. 3, and should not require much explanation.

The lines which we have drawn in so many positions (the shadows of which we have cast), may be used as co-ordinates to locate the shadows of points of any object on any surface. These are all that it will be necessary to find to enable us to draw the perspectives of the shadows of the objects.

There are several methods by which the process of construction may be somewhat shortened, but since we do not intend to make an exhaustive study of the subject of shadows, it is sufficient that the student learn one method thoroughly.

Dimensions and placing for Problem 4, Fig. 31:

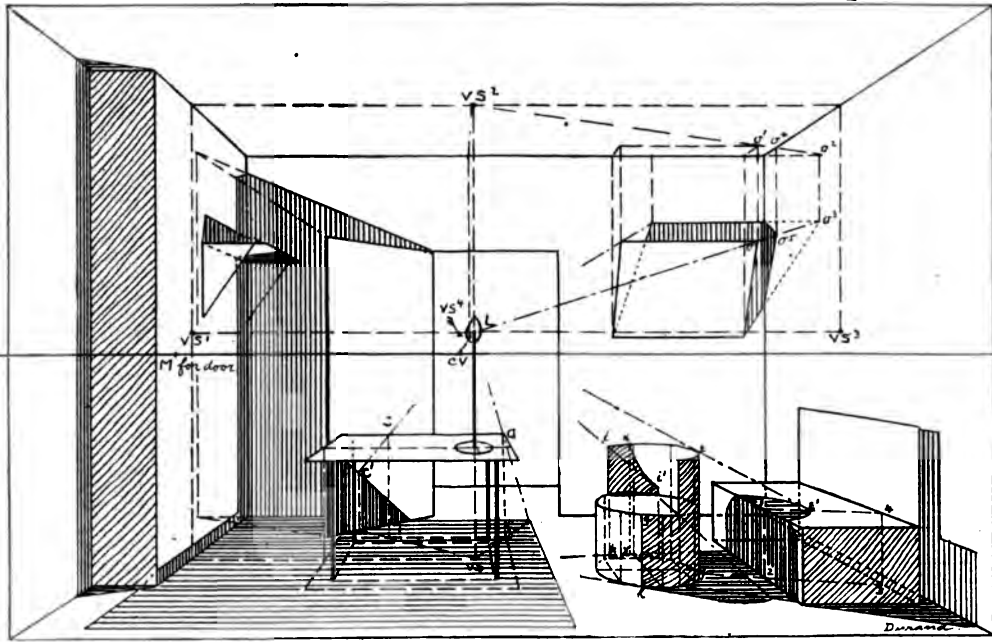
Room, 19′ 6″ wide, 11′ high, and (the portion shown) 9′ deep. Light, 6″ R. of C. V. and 5′ back of P. Pl. Table, 4′ 6″ long, 3′ wide and 2′ 9″ high; front right corner, 1′ 3″ R. and 2′ 9″ back. Barrel chair, 2′ 3″ diameter; height of seat, 1′ 6″; axis, 4′ 3″ R. and 3′ 9″ back. Picture on rear wall, 4′ long and 2′ 9″ high, top 9″ forward. Door, 3′ 6″ by 8′ 3″. Every other dimension is left to the judgment of the student.

To make the problem as simple and as clear as is possible, all objects in Fig. 31 are represented by but a few lines, these giving merely the locations, proportions, directions of edges, etc., just as an experienced draftsman would make his construction. Thickness, decorations, cornices, panels, etc., can be sketched in, free-hand, after the main shadows have been constructed. For the same reason, invisible lines are left out wherever they are not necessary for the construction of the shadows.

Solution.—As suggested before, we will drop perpendiculars (co-ordinates) from points in the outlines of the different objects to the floor, the walls, and the ceiling, and will cast their shadows thereon, using as many of these perpendiculars as may be needed to determine the outlines of the shadows of those objects.

Beginning with the table, we cast the shadow **a-b** to find the shadow of point **a**, then find the shadow of the next corner, and so on. On two sides the points

Prob. 4. Fig. 31.



so found are connected by straight lines. In the rear, the shadow strikes the open door. The shadows of two points of the rear edge of the table are sufficient to establish the shadow line on the door. Point **c** is one of these, and **c-d** is the co-ordinate, the shadow of which we must find. All other points can be located by the student without further information.

Next is the chair. Here we are to find the shadows of curved lines. The shadow of the chair falls partly on the floor, and partly on the front and on the seat of the Davenport, which stands nearby.

The construction is simple. Let us take **e-f** as one of the co-ordinates. A plane passed through the light and through **e-f** cuts the Davenport in trace **1-2-3-4**. A ray drawn through **e** will locate the shadow of this point at **e′**. All points necessary to draw the line of shadow are found in the same way.

A plane tangent to the side of the chair will touch it in the vertical **g-h**, which forms that part of the visible line of shade which is to be found. On the opposite side, this line (**x-y**) is invisible.

But there is still another shadow to be considered. If we follow up the trace of the plane passed through **line i-k**, of the chair, we find that this line so casts its shadow on the seat and on the inner surface of the

back of the chair, that the portion between **i-k** and its shadow will be dark. From **i-k** to the line of shade it is "shade," and from there to the line of shadow it is "shadow."

The shadow of the edge **i-x** is slightly curved; for this reason at least one more point between **i** and **x** should be cast, unless the drawing is made on too small a scale, in which case the draftsman would guess at the curvature.

The shadow of the picture on the rear wall is constructed with the aid of its top view, which is projected on the ceiling.

The fact that the light and its projections on the rear wall (V-S) fall so close together would make the direct construction very inaccurate.

Line V-S^2-O^1 is nothing other than the horizontal projection of ray **L-O**, and **O**^{2} is the trace of the line on the produced rear wall, while O^3 is the trace on the side wall or the shadow of point O.

All other shadows should be found by the student without further explanation.

Shadows by Sunlight.

Substantially there are to be considered but three directions of the light. First, that from the sun when it is directly in front of the observer. Second, that from the sun when it is squarely at the side of the observer. And third, that from the sun when it is behind the observer. If we stand on the west shore of a large body of water, Lake Michigan, for instance, and look east, we shall have the sun before us the whole morning, directly at one side at noon, and back of us through the afternoon.

Looking at 1, Fig. 32, we note that the shadow of the obelisk resembles that which might be cast by artificial light. This is because the sun, being in front of the spectator and back of P. Pl., is visible in the picture just as a candle or lamp would be. But the vanishing point for the shadows is located somewhat differently from that in the problem dealing with artificial light. As the sun, like the horizon, is considered to be at infinite distance, the vanishing point for the shadows is always in the horizon.

When the sun is directly to the side of the observer, II, Fig, 32, the rays are parallel to P. Pl., and consequently, neither the rays of light nor the shadows have any vanishing point.

In the third position, III, Fig. 32, the vanishing point of the shadows is in the horizon, and the vanishing point of the light is directly below it. See Problem 7, Figure 35.

1. The Sun in Front of the Observer.

Problem 5, Fig. 33.—Cast the shadow of a Roman cross, shaft, 10′ high; cross-bar, 6′ long; right section of shaft and bar, 1′ square; upper side of cross-bar, 1′ 6″ below top of shaft.

Placing.—Front vertical edge, 2′ L. of C. V., and 12′ back of P. Pl. Front face to be at an angle of 40 degrees L. to P. Pl. Distance, 14′. Horizon, 6′ above ground. Scale, ½″ to 1′.

Solution.—After the perspective of the cross is finished, drop perpendiculars (coordinates) from the end of the cross-bar to the ground, i. e., construct the top view, then cast the shadow as in the case of shadows by artificial light.

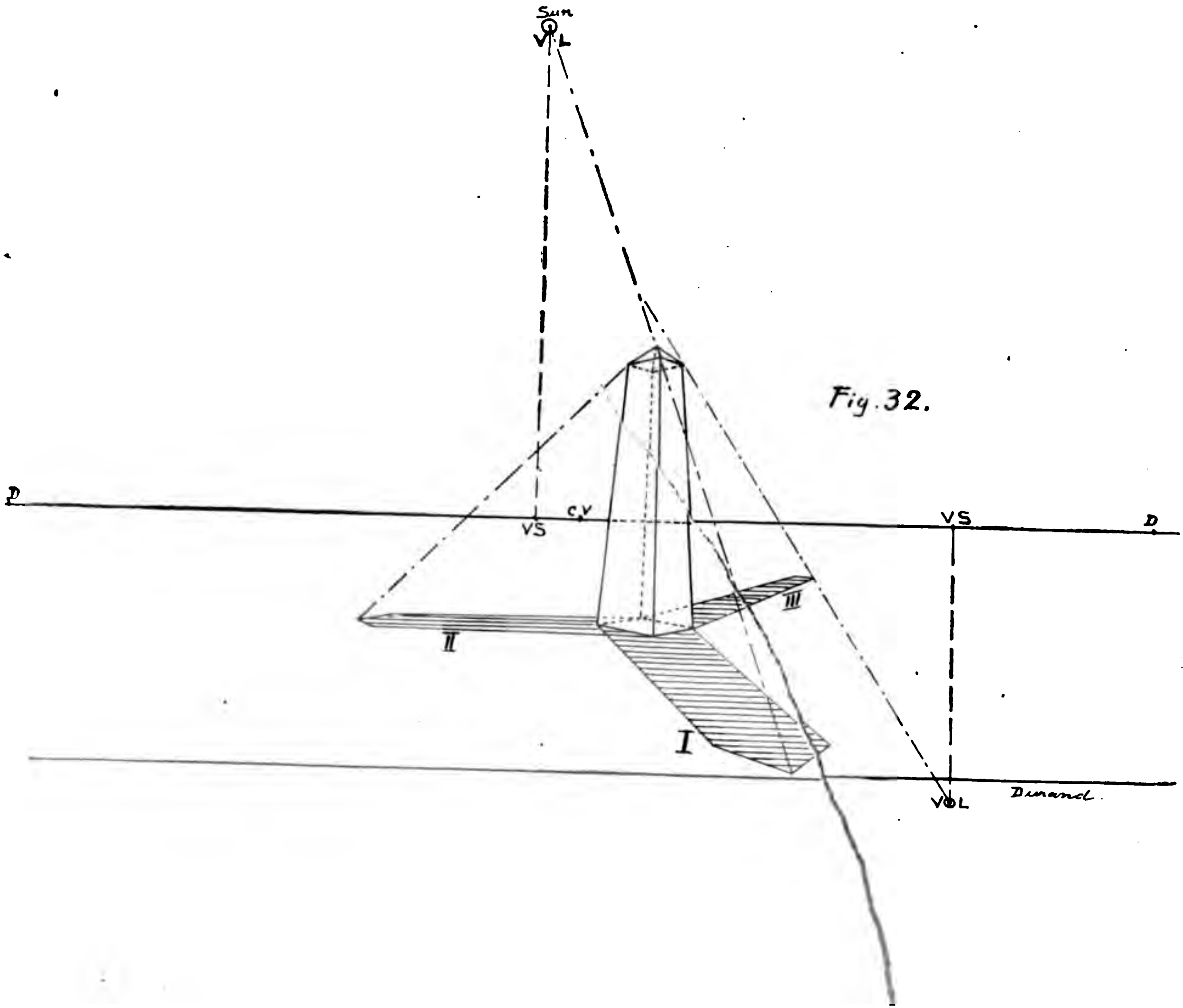
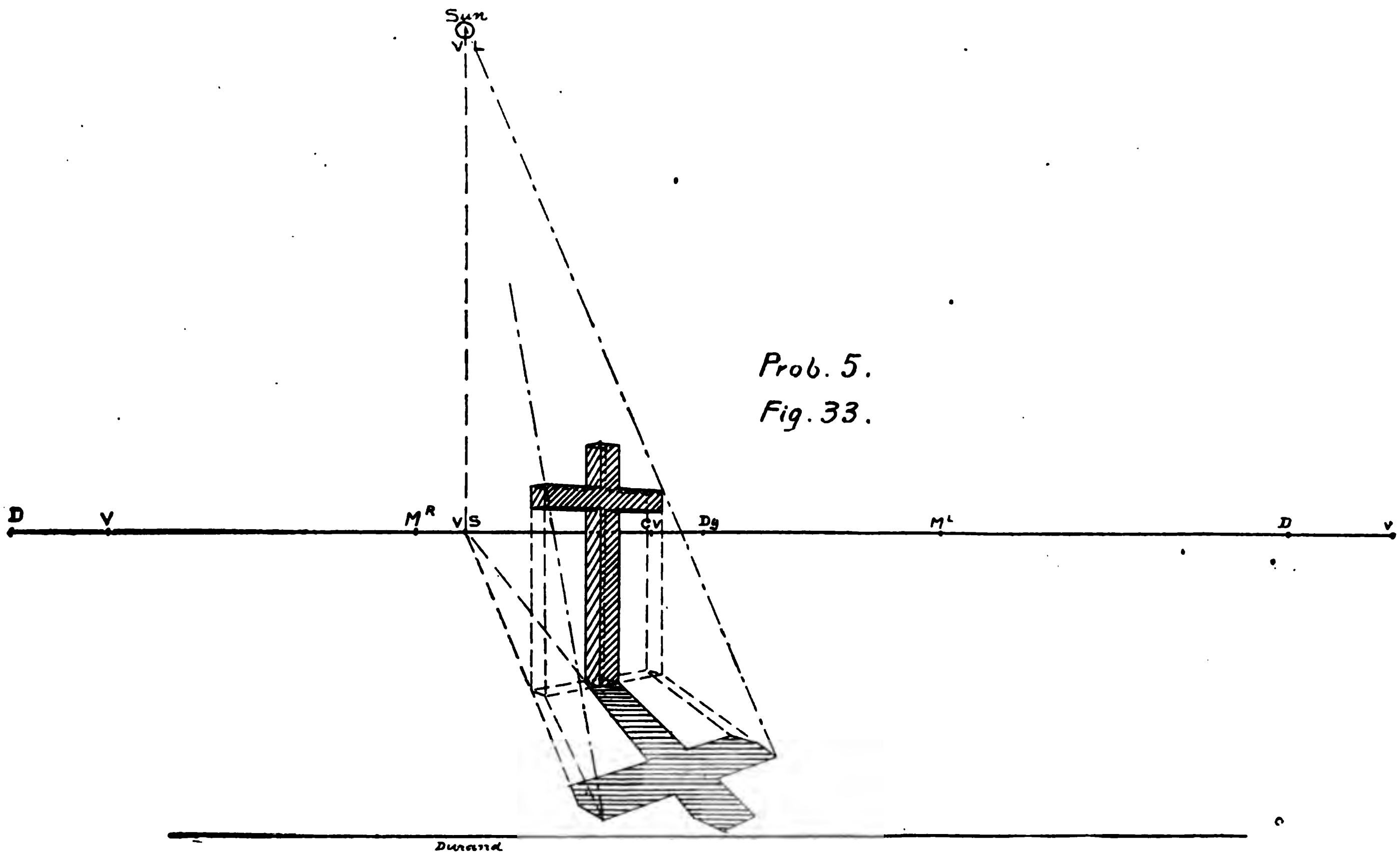
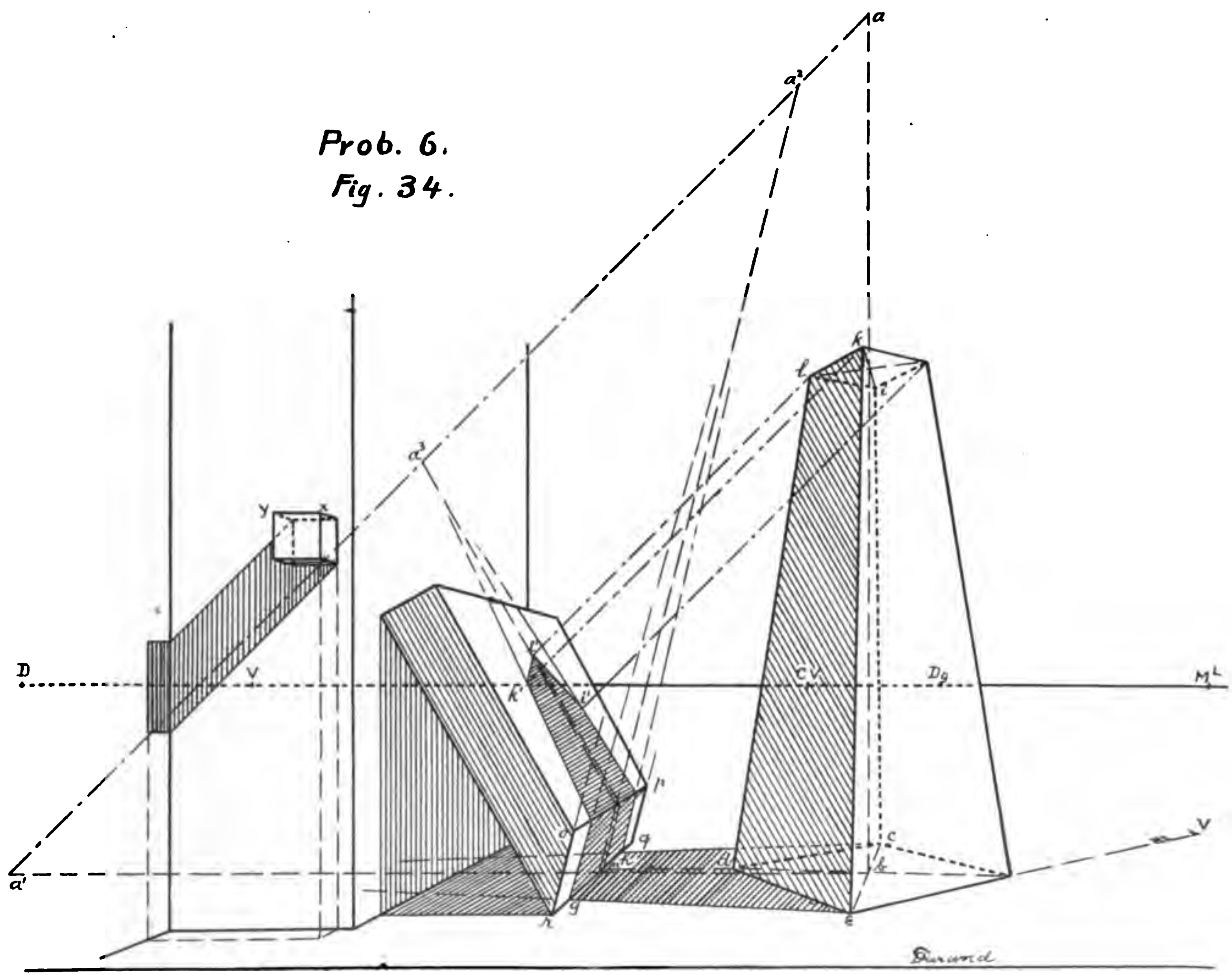


Fig. 32.


Sun
V'L
D
V
M^R
VS
CV
Dg
M^L
D
V
Prob. 5.
Fig. 33.
Durand

Prob. 6.
Fig. 34.



II. The Sun Directly to the Side.

Problem 6, Fig. 34.—Cast the shadows of a group of objects arranged as shown in the given figure.

Solution.—The shadow of the truncated pyramid is found by casting the shadow of its axis on the ground, and drawing **a′-e, a′-d**, and **a′-c**, thus finding points **g**, **i**, and **h** in the lowest edge of the plinth. Then cast a shadow of **a** on the produced rectangle, **o-p-q-r**, and connect the point found with **g**, **i**, and **h**, and so continue, to obtain the points of shadow in the other face of the plinth.

It is not necessary to explain the construction of the shadow of the plinth leaning against the side wall.

As the rays of light are parallel with the front walls, the shadow cast by the projecting square prism upon that wall would extend to infinity, unless intersected by some other surface, as here assumed. To find its shadow upon that surface, drop a perpendicular from **x** or **y**, etc.

III. The Sun Back of the Observer.

Problem 7, Fig. 35.—Cast the shadow of a pole 20′ high, 6″ thick at the base, and 2″ thick at the top; axis located 3′ back of P. Pl. and 8″ R. of **CV**. The rays of light to be at an angle of 60 degrees R. to P. Pl. and 30 degrees to the ground.

Solution.—First, make a geometrical drawing of a 60x30 degree triangle of any size, then construct the perspective of this triangle side **a-b** vertical, coinciding with the picture plane, and side **b-c** at an angle of 60 degrees R. to P. Pl., locating point **c** at c′. Draw **a-c′** and produce it until it intersects a perpendicular from **V. S.**, then this point of intersection **(V. L.)** is the vanishing point for the rays of light.

Proof.—Triangle **a-b-c′** is a vertical plane inclined to P. Pl., and since the P. Pl. is assumed as vertical, their line of intersection (trace) must also be vertical. Consequently, **a-b** and **a-c′** being elements of the plane **a-b-c′**, the points in which they intersect, **V. S.** and **V. L.**, must be their traces in P. Pl., i. e., their vanishing points.

After this is accomplished, the shadow of the pole can be constructed easily.

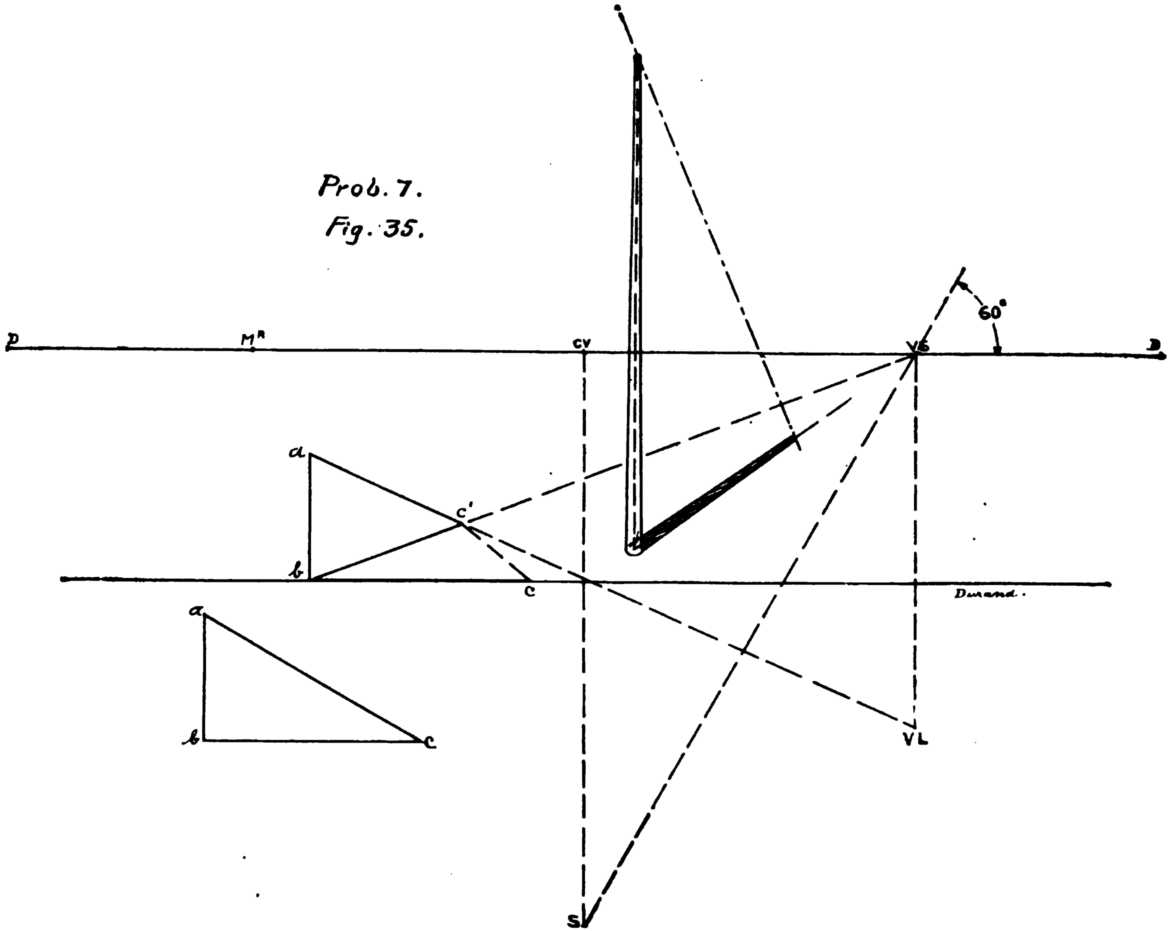
From Prob. 7, Fig. 35, we learned how to cast the shadows when the angle of the light is given, but this is only of theoretical value. In practice the angle is hardly ever given. The draftsman so assumes the light as to secure a satisfactory effect of light and shade in his picture, regardless of its angle.

In starting to draw the shadows in a picture, we first assume the vanishing point for the shadows, and note the result. If this should be unsatisfactory, the direction of the light should then be changed.

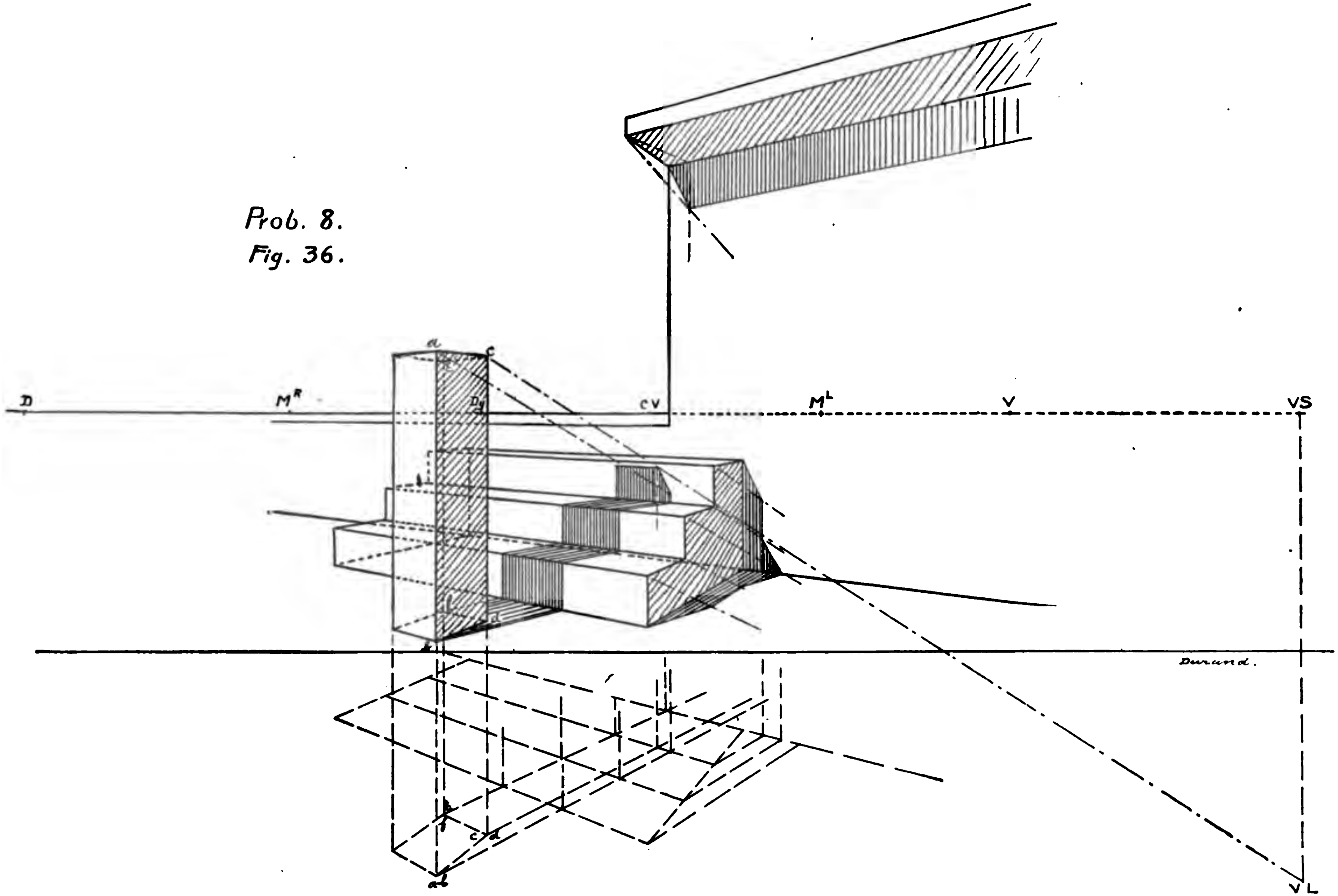
Problem 8.—Construct the shadow of a group of objects such as is shown in Fig. 36.

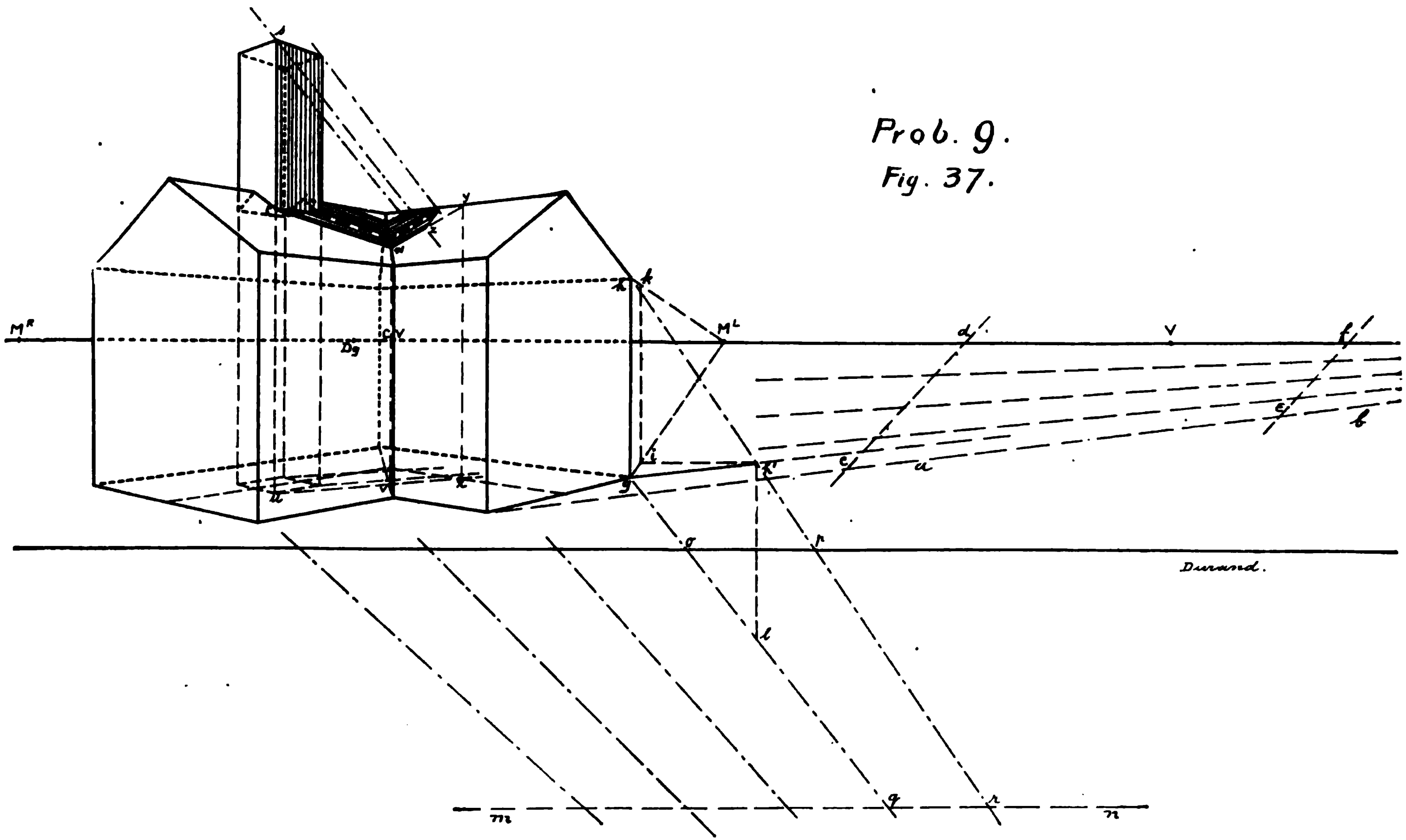
The shadow of the square prism on the flight of steps is found by casting the shadow of **a-b**, **c-d**, and **e-f**. To facilitate this construction, and to make it more accurate, sink the ground plan some distance below the ground, draw the traces of the planes of light which pass through the edges just named, and project the points of intersection up to the perspective drawing, thus finding the traces of these planes on the steps, i. e., the shadows of the edges **a-b**, **c-d**, and **e-f**. Further explanation should not be necessary.

The construction of the shadow of the plinth, which crowns the wall, has been described in Shadows by Artificial Light, Prob. 3, Fig. 30.


Prob. 7.
Fig. 35.
60°
P
M^R
CV
VS
D
a
c'
b
c
Durand.
a
b
c
VL
S

Prob. 8.
Fig. 36.





Problem 9.—Construct the shadows of the object shown in Fig. 37.

Solution.—An object might be in such a position that the light would strike all its visible faces, unless we were to assume the sun to be at such a small angle to the picture plane as to put the vanishing point of the shadows, as well as the vanishing point of the light out of reach.

If this be the case, we can overcome the difficulty in a very simple although not quite convenient way. After the direction of the shadow has been established by drawing the trace **a-b**, we may consider the hori-

zon as a second trace parallel with the first. Then draw two parallels **c-d** and **e-f**, intersecting the trace **a-b** and the horizon, and divide them into a like number of equal parts. Now, connect the corresponding subdivision points of these lines. Then, all these lines just drawn will be directed to the distant vanishing point of the shadows. It is not difficult to cast the shadows approximately parallel with those lines.

We utilize a similar scheme for showing the direction of the ray of light, i. e., by assuming one ray and then constructing a second ray parallel with the first.

This is done by the following method. Let us cast the shadow of the right, rear edge, **g-h** of Fig. 37. If the line **h-h′** represents the ray assumed, then **g-h′** is the shadow of **g-h**. Now, we are to construct a ray parallel (in perspective) with **h-h′**.

First draw the parallels **g-M.L.** and **h-M.L.** (same vanishing point), then project **h′** over to **g-M. L.** and erect **i-k** equal to **g-h** (parallels between parallels). Now, set off **i-k** vertically below **h′**, and draw **g-l**, which will be parallel with **h-h′** (**l-h′** equals **i-k** equals **g-h**).

To draw more rays parallel with the first one, **h-h′**, assume the ground line as one, and **m-n** as the other of two parallel lines intersecting the produced rays **g-l** and **h-h′**. Then set off **o-p** and **q-r** on the ground line and on **m-n** respectively, as many times as desired. The points so found will give us the proper direction for a like number of rays which are parallel with the first ray, **h-h′**. All these rays, if produced, will meet in the distant vanishing point of the light, and all the rays necessary for the construction of the shadows may be drawn approximately parallel with them.

To cast the shadow of the chimney, we pass a plane through the produced edge **s-t-u**; then **u-v-x** is the trace of this plane in the ground plan. Project **v** and **x** to the roof, and draw **t-w-y**, the trace of the cutting plane in the roof. Then cast a ray through **s** to find **z**, and so continue, to determine the points of shadow of the other edges of the chimney.

It should not be necessary here to work out the problem any further, inasmuch as the construction of all other shadows has been demonstrated in previous problems.

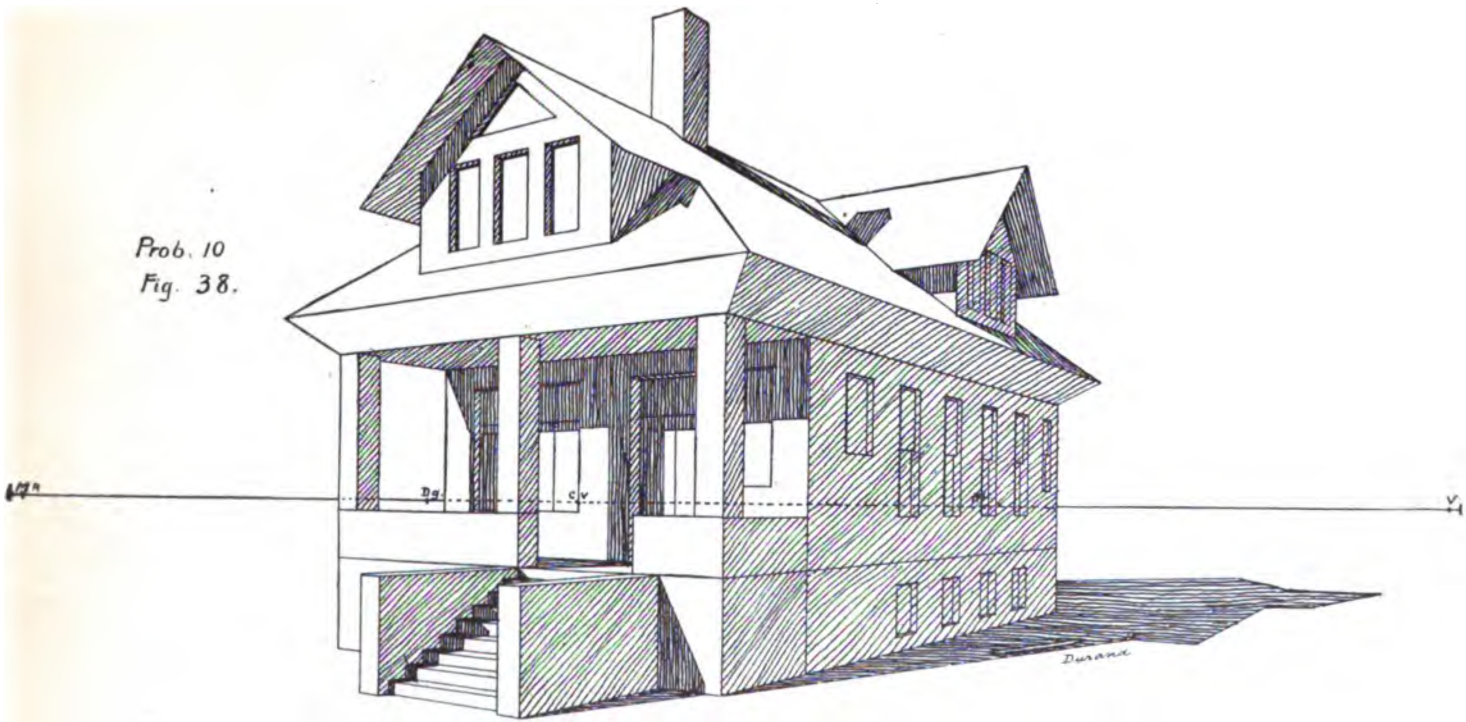
Problem 10, Fig. 38.—Construct the shadows of a building.

The "bungalow," which is considered "given," may be copied, but if time permits it will be better for the student to make his own perspective drawing of a similar building having the same simplicity as the given figure.

There is no need of any explanation for the solution of this problem, inasmuch as all necessary constructions have been demonstrated previously.

Suggestions.—To make the constructions accurate, and to keep the student from getting confused, it is advisable to sink the plan of the building at least 12′ below the ground (see Prob. 8), and to finish one construction at a time, to ink the results and to erase the construction lines before proceeding with the next.

For practice, the shadows of all objects drawn previously as problems in perspective might be constructed.



Final Remarks.

The casting of shadows may seem to be of little value, and yet, in order to give the correct appearance to any object, it is indispensable. But, while it may be necessary, even for an experienced draftsman, actually to construct the shadows for a complex body, any person who is familiar with their construction will be able to cast them for simpler objects, more or less accurately, wholly from imagination—i. e., to construct them, in his mind only, while others, unfamiliar with the subject, will be altogether "at sea," as all students know from their own experience.

COURSE B.

ELEMENTARY MACHINE DESIGN.

BY ALBERT W. EVANS
AND FRED W. ZIMMERMANN

Elementary machine drawing or **machine design** includes the drawing of simple machinery, standard fastenings, and machine parts or details, and also the consideration and application of the rules and formulae from which the standard sizes are worked out, so that each part will have the necessary strength without being too heavy or cumberson.

In making machine drawings all the rules and principles learned under projection drawing find application. In the past the student has been chiefly concerned in learning these principles and rules, but in machine drawing these are only a part of his equipment, and it is the design and drawing of a usable, well constructed piece of a machine of some sort that he is striving to accomplish.

Tracings.—In the practical draughting office the draughtsman makes his drawing in pencil on drawing or "detail paper", but instead of inking on the paper, he places a piece of semi-transparent tracing cloth over the drawing, rubs the cloth with powdered chalk or tracing cloth powder, and then inks or traces directly on the cloth the lines which he sees on the paper underneath. The advantage of this is that any number of blue prints can be made from a single tracing with far less work, and more accuracy than it would take to make another drawing of the same object. At least a part of the drawings in this course should be inked on tracing cloth, or "traced" in order to make the school work conform as nearly as possible to actual practice.

Blue prints are made by placing the tracing in a special blue print frame over pieces of paper coated with an emulsion which undergoes a chemical change and turns blue when exposed to strong light. The black lines of the tracing stop off the light from the prepared paper and leave a white line on the blue surface. When the paper has been sufficiently exposed to the light it is washed for about ten minutes, or until all the unchanged emulsion is cleaned off, making the blue print permanent. The prepared paper must be kept in a dark, dry place to avoid deterioration, and only opened in yellow light or very subdued daylight.

Lettering.—Great care should be taken with the title and all printing on a drawing, as otherwise a good plate can be ruined with poorly designed or slovenly lettering. The printing must be large enough to be easily found and read; must not be so large as to overbalance the drawing; and must not be so conspicuous as to attract the eye to the exclusion of the remainder of the drawing.

The principal words in the main title should be Roman or Gothic capitals, either vertical or slant, solid or open face. Less important words can be Roman or Gothic small letters, Shop Skeleton or Geometric alphabets. Make letters of the main words from 3/16″ to ½″ high according to the size of the drawing and the number of words in the title. The main title should be compact, not extended over the entire paper. In general it should be symmetrical about a vertical center line. The principal words should stand out plainly. Minor words such as prepositions and less important statements, should be subordinated. The sub-titles of each exercise should be Shop Skeleton

capitals from ⅛″ to 5/32″ high. Any notes on the drawing should be Shop Skeleton from 3/32″ to ⅛″ high.

Materials Used in Machine Construction

On account of its great strength and cheapness, iron is almost universally used as the chief metal in machine construction. Iron is manufactured in three forms, each one having special adaptations for certain uses.

Cast iron contains from two to six per cent. of carbon, and varying amounts of silicon, sulphur, manganese and phosphorus; its adaptability for certain uses depending to a great extent on the proportions of the above elements. It is crystalline in structure, and breaks rather easily under a sudden shock. It melts at about 2100° Fahrenheit (F) and can be run into moulds of any desired shape. These moulds are usually made by pressing sand around a wooden model the size and shape of the casting desired. The model or pattern is then removed and the molten metal poured into the cavity. Cast iron can not be worked or hammered into shape, nor can it be welded. Under compression, or pressure, cast iron has a strength of about 90,000 pounds per square inch. That is a piece of metal, one inch square, will just support 45 tons. Under tension, or pulling apart, the same cast iron would have a strength of only about 20,000 pounds per square inch. The Specific Gravity of cast iron is about 7.25, or in other words it is about seven and one- fourth times as heavy as water. By referring to the appended table, the strength, specific gravity, usual factors of safety, etc., of the ordinary materials of construction can be compared.

TABLE I.

Average Strength, Specific Gravity, Factors of Safety and Melting Points of Various Materials of Construction.

Material.	Ultimate Strength. Tension	Com-pres-sion.	Shear-ing.	Spec. Grav.	Factors of Safety.	Melting Point (F)	Wt. per Cubic Inch Lbs.
Cast Iron	20,000	90,000	20,000	7.25	6 to 9	2100°	.261
Wrought Iron	50,000	48,000	40,000	7.7	5 to 8	3000°	.278
Soft Steel	60,000	60,000	55,000	7.8	5 to 8	2500°	.281
Brass	35,0 0	40,000	28,000	8.3	7 to 9	1800°	.303
Copper	25,000	40,000	30,000	8.8	7 to 9	2000°	.319
Bronze	27,000	40 000	49,000	8.9	7 to 9	1700°	.320
Lead				11 3		620°	.410
Wood, Pine	11,000	5,500	2,400	0.45	10 to 12		.0162
Wood, Oak	14,000	8,000	4,000	0.77	10 to 12		.0277
Stone		6,000		2.5	20		.0903
Concrete				2.0	2)		.0723
Brick		4,000		1.8	20		.0648
Leather	4,000				8 to 16		

By factor of saftey is meant the usual ratio of the ultimate strength to the safe working load allowed on any particular piece of material. For instance by referring to the Table it will be seen that a piece of steel one inch square will just support 60,000 pounds, but in order to avoid accidents, that piece of steel would be made from five to eight times as large, and therefore from five to eight square inches would be used to support 60,000 pounds. No definite factors of saftey can be given, as a piece of material that is subject to shocks or blows will have to be made relatively much heavier than one that only supports a quiet or dead load.

Wrought iron contains practically no carbon, and has a definite fiber or grain. Its melting point, about 3000° F, is so high that it is almost impossible to make it fluid enough to cast into moulds. It is usually rolled or hammered into the desired shape in the rolling mill or the blacksmith shop. Wrought iron can not be broken with a hammer like cast iron, and it can be bent and welded. Notice that its tensile strength is almost the same as its compressive strength. Until the last few years, wrought iron was used almost exclusively for boiler plate, rods, beams, etc., requiring great tensile strength, but the perfection of the Bessemer process for making steel cheaply and quickly has caused steel to supplant wrought iron for most purposes.

Steel contains from .15 to 1.6 per cent of carbon, and varies between wide limits in hardness and strength according to the percentage of carbon, silicon, sulphur, manganese, and phosphorus it contains, and also according to its methods of manufacture. Mild, soft or machinery steel contains from .15 to .5 per cent of carbon, and can be welded, bent cold, and hammered without breaking. Steel containing from .5 to 1.0 per cent of carbon is somewhat harder, and is used for rails, beams, etc. Steel having from 1.0 to 1.6 per cent of carbon has the unique property of becoming extremely hard when heated and then suddenly cooled by plunging in water or oil. The metal thus treated is said to be tempered, and can be easily broken by a sudden shock. It is used for tools having cutting edges, knives, springs, etc. Articles made from steel are rolled into shape, as rails, beams, and sheets, formed under the hammer; as engine shafts and connecting rods; or cast in moulds much the same as cast iron, excepting that it is more difficult to get perfect castings. Its melting point is about 2500° F.

Copper is a reddish metal, soft compared with iron. It can be cast into moulds and rolled or hammered into any desired shape, either hot or cold. It is much more expensive than iron, but is also much more durable when exposed to the weather, not rusting away as iron does. It is used largely for electrical work, on account of its high conductivity and durability. It melts at about 2000° F.

Brass is an alloy, that is, it is made by mixing together other metals, and is usually composed of two parts copper to one part zinc. It is durable, has a good color, takes a high polish, and is largely used for ornamental work, small fittings, bearings, etc. It can be cast and is easily worked.

Bronze or gun metal is an alloy composed usually of nine parts copper to one part tin. It was formerly used for making cannon, now it is used for ornamental work, bearings, etc.

Lead is an exceedingly soft and heavy metal. Notice that no figures are given in the Table for its ultimate strength, as it is not suited for any work where it is put under strain. Lead is very durable, and is used largely for plumbing, and in places which are subject to the corroding action of chemicals. Its melting point is 620° F.

Babbitt Metal is composed of copper, antimony and tin. It is much used for making bearings, as it is soft and easily lubricated, and it melts at such a low temperature that it can be cast right in place in the bearing around the shaft, thus saving expensive fitting in the machine shop.

Wood varies greatly in strength, according to the kind of tree it is taken from, its age, and even the kind of soil in which the tree grows. The same piece is

much stronger with the grain than across it. Weight for weight, wood is stronger with the grain than steel, but on account of the ease with which it is split one way, and its bulk, it is little used in machine construction, except for the frames of some machines, and for the patterns from which castings are made.

Stone, Brick and Concrete are chiefly used in machine construction for the foundations of heavy machinery.

Leather is used principally as belting for transmitting rotary motion from one shaft to another.

Section lines. Figure 1 shows a scheme by which one material can be distinguished from another on a drawing where they are shown in section. Section lines are usually ruled about 1/16 inch apart with the tee square and 45° triangle, the spacing ordinarily being done with the eye alone, although several forms of mechanical spacers, or section liners are on the

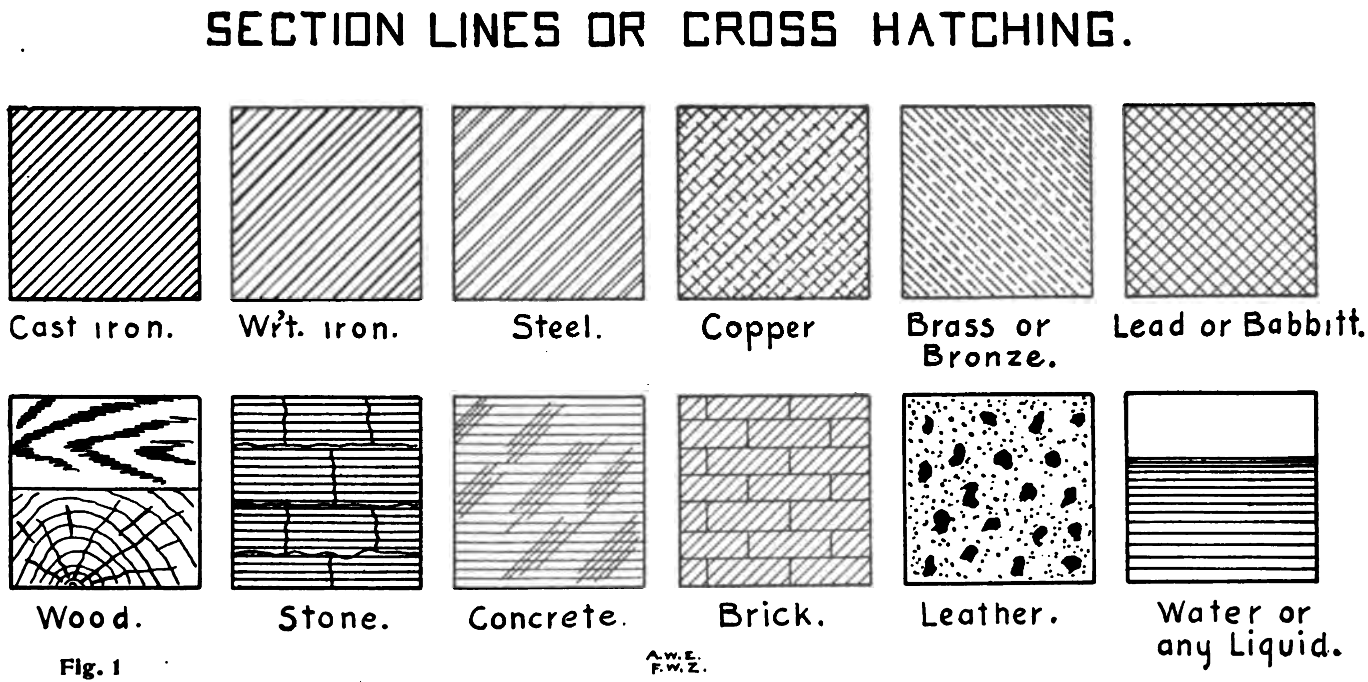


Fig. 1

market. The lines may be sloped either to the right or left, adjoining pieces usually being cross-hatched in opposite directions, so that the pieces may be easily recognized as separate.

Fastenings.

Among the common methods adopted for fastening two or more pieces rigidly together may be mentioned cementing or gluing, soldering or brazing, nailing, screwing, riveting and bolting.

Cementing or **Gluing** is only applicable to work that is not to be taken apart again, and to material that is sufficiently porous to allow the glue to become attached to the adhering surfaces. Wood and leather conform to these requirements, and with these materials well made glued joints are almost as strong as the material itself.

Soldering and **brazing,** with metals, takes the same place as gluing with wood, a well made joint being practically as strong as the unjoined metal.

In welding the two pieces become practically one and may be considered as such.

Nailing is only applicable when at least one of the pieces to be joined together is soft enough to permit a nail to be driven into it, and rigid enough to hold the nail from pulling out. This practically limits its use to wood. Nails are an economical fastening, because they are cheaply made and easily and quickly driven in place. The joint is not especially strong, and can be readily pulled apart. Figure 2 (a) shows the usual form of wire nail.

Screws. A joint made with screws is much stronger than one made with nails, but it takes longer to make it, and the screws are much more expensive to manufacture than the nails. A screw may be used to fasten pieces of any kind of material together that have sufficient rigidity to hold the screw thread metals as well as wood. Screws are made in two standard forms. First those which are to be used with comparatively soft materials, in which they can form their own thread, i. e. the regulation wood screw, and second those which are to be used with hard material, and are obliged to have the hole drilled and threaded the exact size of the screw before it can be put in place, i. e. the machine screw. Standard wood screws are shown at (b) and (c), Figure 2, and a standard machine screw at (d). Notice that the wood screw is pointed, so that on turning it will force its way into the material after it is once started. Screws are usually made of steel, but other metals, as wrought iron, brass, copper, etc. are sometimes used.

Rivets are cheaply made, and form a strong secure joint. The principal difficulty with their use being that they are hard to get out, if the pieces have to be taken apart again. They are used chiefly for permanent work such as boilers, bridges, structural steel in buildings, etc. The holes should be drilled slightly larger in diameter than the rivet, and then the end of the rivet hammered (either cold or red hot) with hammers or a machine riveter until the hole is completely filled, and the required shaped head formed. Rivets are usually made from soft steel, wrought iron or copper, it being necessary for the material used to be sufficiently malleable to be hammered into the desired shape. Standard forms and proportions of rivets are shown at (e), (f(, (g) and (h), Figure 2. (e) is called the button head, (f) the conical head, (g) two forms of the steeple head and (h) the countersunk head. The standard dimensions are proportional to the diameter (D) of the rivet. For a

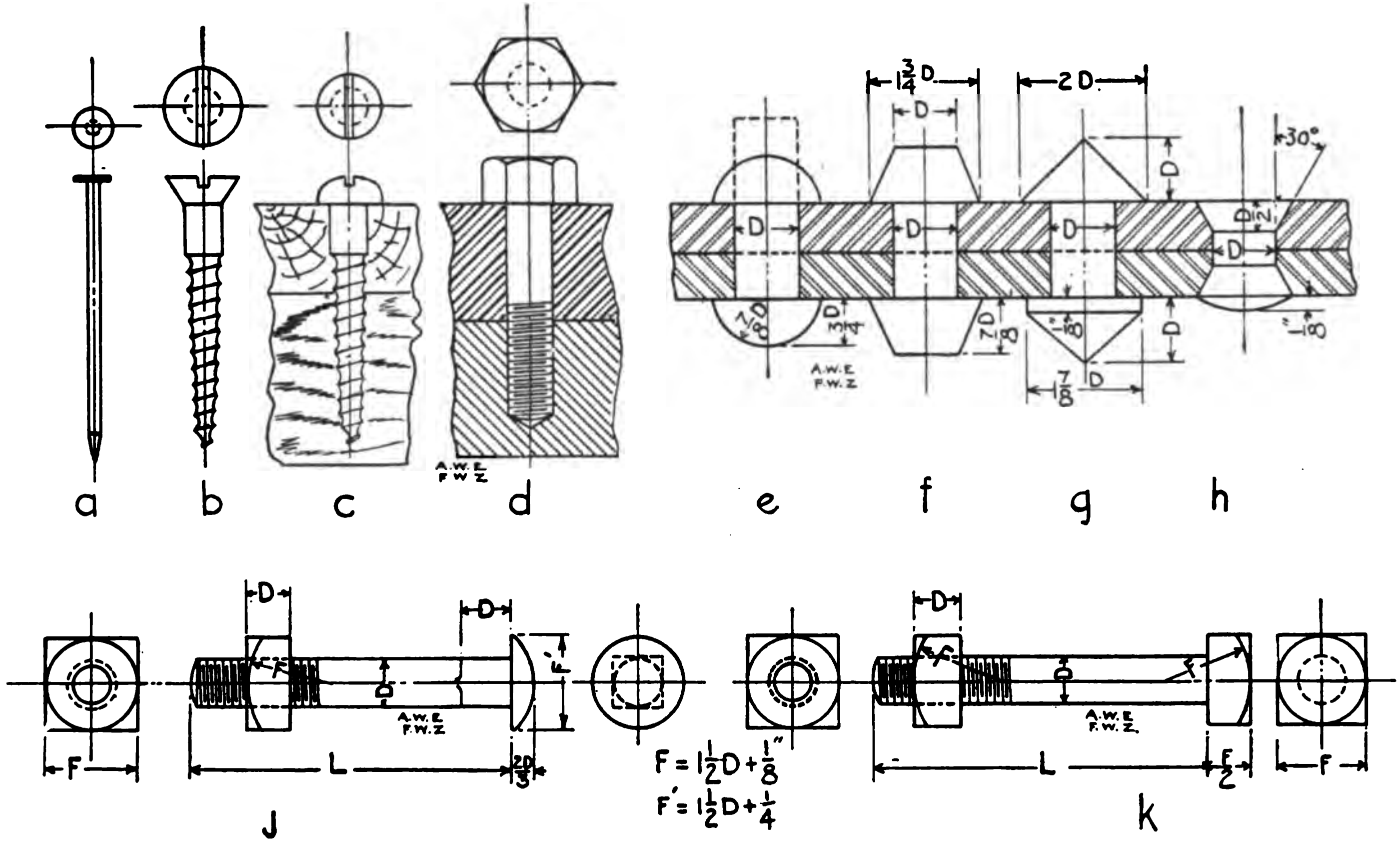


Fig. 2

larger or smaller size of rivet, all the other dimensions would increase or decrease proportionately to this diameter. The dotted lines in (e) show the shape of the rivet before the head is formed.

Bolts and Nuts.—A bolt with its nut forms practically a rivet having one removable head, and as such it has the chief advantages of the rivet, excepting cheapness, with the added advantage of being easily removed. It also resembles a machine screw, in which the nut takes the place of the threading in the lower plate, the hole being drilled entirely through both pieces that are being held together. Bolt heads and

nuts are given various shapes, the chief of which in machine bolts are the square and hexagonal forms, on account of the facility with which they can be turned with a wrench. In bolts used for wood the custom is to employ a square nut and a round bolt head, and then square the shank for a short distance below the head to keep it from turning in the hole. A bolt designed to hold two or more pieces of wood together is shown at (j) Figure 2, and a machine bolt with a square head and nut, designed to hold pieces of metal together is found at (**k**). The standard proportions for hexagon machine bolts and nuts are given on Plate I, Exercise 6.

A screw thread is the helical projection on a screw or bolt, and is usually formed on an engine lathe or a screw machine. The blank bolt is fastened in the lathe in such a manner that, as the bolt revolves, a cutting tool having an edge the exact shape of a section of the groove, travels along the face of the bolt parallel to its axis, at a rate of speed which is proportional to the speed of turning of the bolt. That is, if the threads are to be 1/16″ apart, the tool will move 1/16″ while the bolt makes one revolution.

The Pitch of a screw thread is the distance that the cutting tool moves forward, while the screw or bolt makes one revolution in the lathe; or it is the distance that the nut moves along the bolt in one complete turn. For a single thread screw it is the distance between the points of neighboring threads. The Pitch of a double thread is shown in Figure 4 (b). For further illustrations see Plate I.

The Nominal Diameter of a screw or bolt is the diameter at a place where the threads have not been turned, or the diameter from outside to outside of the threads.

The Effective Diameter is the diameter at the root of the threads.

The Depth of the Thread is equal to the distance from the root of the thread to the point, measured perpendicularly to the axis of the screw.

Obviously, the greater the pitch the deeper the grooves will be, and hence the smaller the effective diameter, which makes a weak bolt. If the pitch is made smaller the threads become too small, and it takes only a slight pull to break off or strip the threads, which also makes a weak bolt. Hence it is necessary to work out a scheme which will equalize these conditions, and produce a bolt uniformly strong, each part being as nearly equal in strength to every other as possible. Several different systems have been originated, the Sellers' or United States Standard Thread being the one that is usually used in this country. (See Exercise 1.)

Plate 1.

Exercise 1.—Draw five threads in section of the Sellers' or U. S. Standard thread, suitable for a wrought iron bolt 4″ in diameter. Scale, four times full size.

Let P=pitch of the threads;
  b=depth of the whole V;
  b_1=depth of the thread;
  D=nominal diameter of bolt;
  D_1=effective diameter of bolt;
  n=the number of threads per inch, and is therefore the reciprocal of the pitch or 1/P.

Then by algebra $P=1/n$.

For uniform strength the proportions of the thread should be worked out by means of the following formulae:

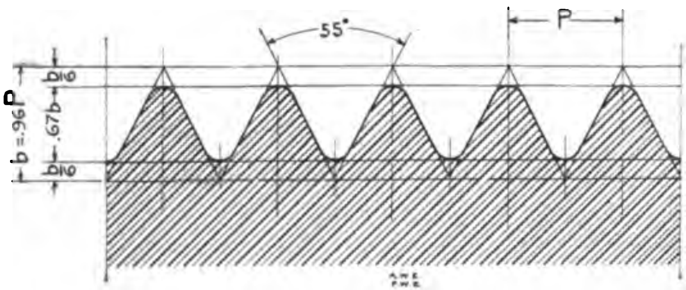
$P=0.24\sqrt{D+0.625}-0.175$ 1.

$b=\sin 60°\times P=0.866\ P$, as $\sin 60°=0.866$. 2.

$b_1=3/4\ b$. 3.

$D_1=D-3/2\ b$. 4.

The given angle of thread, 60°, has been found in practice to give the greatest strength. The Sellers' thread has been adopted by the United States Government, and by most of the leading engineering and iron and steel works of this country. The sharp V as shown by the dotted lines, and in Exercise 4 is sometimes used instead, and only differs from the Sellers' in that the sharp points of the threads are not



WHITWORTH STANDARD THREAD.

Fig. 3

cut off. The Whitworth thread, the English standard, has the points rounded, and uses an angle of 55° instead of 60°, as is shown by Fig. 3. Notice that the section lining, alternate dark and light, shows the material, wrought iron. See Fig. 1 for other forms of section lining. To find the pitch (P), substitute for D in the formula its value (4″), as given in the statement of the problem, and solve the same as for X in algebra. Solve the remaining formulae in the same manner. The drawing is made four times full size, because if made exact size, the screw would be too small to show the form of thread well. Border lines are to be 12″x17″.

Exercise 2.—Draw four threads in section of the square thread applied to a steel screw. Pitch ¾″. Scale twice full size. On two of the threads show the form, dotted, of the knuckle or rounded thread.

Lettered dimensions have the same meaning as in Exercise 1. The pitch (P) of the square and knuckle threads is usually made twice as great as the pitch of the Sellers' thread for bolts of the same diameter, so that

$P=2(0.24\sqrt{D+0.625}-0.175)$ **5.**

The square thread is usually used for transmitting motion, as in the screws that move the cutting tools on a metal working lathe, and in the screw of a carpenter's or machinist's vise. The knuckle thread is used for the same general purpose, but is more easily made and less accurate. Examples can be found in the wooden screws of carpenter's clamps and vises. The section lining, light lines spaced alternately far and near, shows the material, steel.

Exercise 3.—Draw a section of the end of a wrought iron water pipe, showing the standard pipe threads. Nominal inside diameter 4″. Scale three times full size, or 3″=1″.

As pipe joints must be steam, water and gas tight to prevent leakage, the problem of designing the threads is somewhat different from that of designing an ordinary screw thread. To overcome this difficulty the threaded ends are usually made slightly tapering, so that the farther the ends are screwed together the tighter the joint will be. The tapering is usually accomplished by cutting the threads by hand with stocks and dies, which are constructed so as to leave the taper on the threaded end of the pipe. In practice the points of the threads are slightly rounded, but this is not usually shown in the drawings.

Let P=pitch of the threads;
- L=length of the perfect screw;
- D=nominal inside diameter of pipe—i. e., the nearest even fractional diameter, as 1/8", 1/2", 1 1/4", etc.;
- D_1=actual inside diameter;
- D_2=actual outside diameter;
- T=thickness of metal;
- n=number of threads per inch.

L is determined from the following formula by substituting for D_2 and n their values given in the appended table.

$$L=\frac{(0.8\ D_2+4.8)\times 1}{n} \tag{6}$$

$$T=\frac{D_2-D_1}{2} \tag{7}$$

$$P=\frac{1}{n} \tag{8}$$

All necessary dimensions are to be taken from Table II.

Why is the pitch of the standard pipe threads less than that given by the United States standard for the same diameter?

TABLE II.

Standard Dimensions of Wrought Iron Welded Steam, Gas, and Water Pipe.

D	D_1	D_2	n		T
Nominal Inside Diameter Inches	Actual Inside Diameter	Actual Outside Diameter	No. of Threads Per Inch	Actual Internal area	Thickness of Metal
1/8	0.270	0.405	27	0.057	0.068
1/4	0.364	0.540	18	0.104	0.088
1/2	0.623	0.840	14	0.305	0.109
3/4	0.824	1.050	14	0.533	0.113
1	1.048	1.315	11 1/2	0.863	0.134
1 1/4	1.380	1.660	11 1/2	1.475	0.140
1 1/2	1.611	1.900	11 1/2	2.038	0.145
2	2 067	2.375	11 1/2	3 356	0 154
3	3.067	3.500	8	7.388	0.217
4	4.026	4.500	8	12.73	0.237
6	6 065	6 625	8	28.89	0.280
8	7.982	8.625	8	50.04	0.322

Exercise 4.—The Helix or Screw Curve. Make a drawing of a right hand, V thread screw, 3" in diameter and 3/4" pitch, with a section of the nut. Scale, full size. Draw four threads of the bolt and three of the nut, and figure the effective diameter of the bolt.

The Helix is the curve produced on a uniformly rotating cylinder, by a point which is traveling at a uniform rate of speed parallel to the axis of the cylin-

der. By referring back to the definition of a screw thread, it is apparent that a screw thread curve is a Helix. Besides screw threads, examples of the Helix are coiled springs, ropes, twisted iron work, etc.

The construction is apparent when it is seen that the scribing point travels forward a distance equal to the pitch, while the cylinder makes one revolution. Therefore, if the end view of the cylinder is divided into any number of equal parts, say twelve, and the pitch into the same number of equal parts, the intersection of vertical and horizontal projection lines from corresponding points will locate points on the curve.

The curve on the nut appears to run in the opposite direction from that on the bolt, because we see the opposite side of the nut. When the hidden part of the curve is drawn on the bolt, as shown by the dotted lines, it is seen that it agrees with the curve on the nut. A right hand thread is one onto which the nut goes with a right hand or clockwise turn. A left hand thread one on which the nut advances with a left hand or anti-clockwise turn. Figure 4 (a) represents a left hand thread.

The pitch of this screw does not conform to the U. S. standard, being made much larger in order to show a good curve. A screw of this sort would be called a "Special Screw."

Exercise 5.—Application of the Helix to a spring. Make a drawing of a coiled spring, 3″ in diameter and 1½″ pitch. The section of the metal from which the spring is made is to be ½″x⅜″, the ½″ being taken parallel to the axis of the spring.

The construction is the same as in Exercise 4. Make length the same as bolt and nut combined.

Exercise 6.—U. S. Standard Bolt and Nut.—Make a detail drawing of a hexagon head machine bolt and nut, according to the U. S. standard formulae. Let D=¾″ and L=2½″. Scale, full size.

A bolt is only as strong as its weakest part, and hence the problem is to proportion the different parts so that each one will have the same approximate strength as any other. From practice, tests and mathematical considerations the following formulae have been found to give proportions to machine bolts which closely follow the above requirements.

Let D=nominal diameter of the bolt;
L=length of the shank;
F=distance across the flats;
T=thickness of head and nut;
C=distance across the corners.

Then $F=1\frac{1}{2}\,D+\frac{1}{8}''$ for rough bolts, or 9.
$=1\frac{1}{2}+1/16''$ for finished bolts. 10.
$T=D$ for rough bolts, or 11.
$=D-1/16''$ for finished bolts. 12.
$C=(1\frac{1}{2}\,D+\frac{1}{8}'')\times 1.155$ for rough bolts, or 13.
$=(1\frac{1}{2}\,D+1/16'')\times 1.155$ for finished bolts. 14.

R can be found by using the problem, "Three points in the circumference given to draw the circumference."

Instead of constructing the Helix as in Exercise 4, the curves of the threads are drawn as straight lines. This is usually done on medium-sized bolts to save time. The threads may be shaded as shown, or left without shading as in Figure 4 (a) and (b). The pitch or its reciprocal (n) the number of threads per inch is taken from the following table:

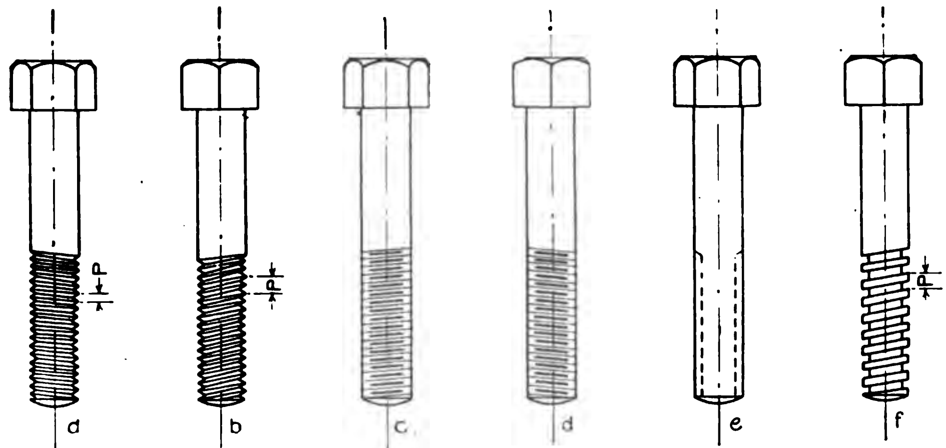
TABLE III.

U. S. Standard Dimensions of Screws, Bolts and Nuts.

D	n				F	C
Dia. of shank inches	Number of threads per inch	Diameter at bottom of threads	Area at bottom of threads	Area of bolt body	Distance across flats per inch	Distance across corners per inch
1/4	20	0.185	0.027	0.049	1/2	37/64
5/16	18	0.240	0.045	0.077	19/32	11/16
3/8	16	0.294	0.068	0.110	11/16	51/64
7/16	14	0.344	0.093	0.150	25/32	9/10
1/2	13	0.400	0.126	0.196	7/8	1
9/16	12	0.454	0.162	0.249	31/32	1 1/8
5/8	11	0.507	0.202	0.307	1 1/16	1 7/32
3/4	10	0.620	0.302	0.442	Figure out	and insert
7/8	9	0.731	0.420	0.601	1 7/16	1 21/32
1	8	0.837	0.550	0.785	1 5/8	1 7/8
1 1/8	7	0.940	0.694	0.994	1 13/16	2 3/32
1 1/4	7	1.065	0.893	1.227	2	2 5/16
1 1/2	6	1.284	1.295	1.767	2 3/8	2 3/4
2	4 1/2	1.712	2.302	3.142	3 1/8	3 5/8
3	3 1/2	2.629	5.428	7.069	4 5/8	5 3/8

Screw Thread Conventions.—The screw thread conventions used in Exercise 6 and in (a) and (b) of Fig. 4 are usually used on bolts which scale from 3/4″ to 1″ in diameter and up, especially on first-class drawings. Care must be taken to space the threads properly (see Table for n) and to have the points of the threads on opposite sides of the bolt in correct relation to each other. Fig. 4 (a) represents a left hand thread. Fig. 4 (b) represents a right hand double thread, in which the moving point travels two spaces for each revolution of the cylinder instead of one. The advantage of this form is that the nut travels twice as rapidly as in the single thread, but, on the other hand, it does not hold as securely. Fig. 4 (c) and (d) shows a convention which is used on nearly all small bolts. The heavy lines represent the bottom of the groove; (c) shows a right hand thread, while (d) represents a left hand one. The convention shown at (e) is used for very small bolts, and on hurried

Fig. 4



A. W. E.
F. W. Z.

drawings, the dotted lines representing the bottom of the threads. Fig. 4 (f) represents a single right hand square thread. Note the pitch of the double thread, Fig. 4 (b).

The Main Title should then be worked out completely in pencil, using the form shown on the plate or designing one from the standard alphabets given. The expressions "Drawn by," "Checked by," "Approved by" and if tracings are made, "Traced by," are ordinarily included in titles, and the usual signature of the draftsman, checker, engineer in charge, and tracer respectively placed after them. It is suggested that under the direction of the instructor, some fellow student check over each drawing carefully before the pupil hands it in, as it has been found in practice that a man taking up a drawing for the first time will often find mistakes that one who has worked over it for a long time fails to discover.

After the pencil work has been completed and approved, the plate should be inked as usual, or traced as described under Tracings, page 49. When tracings are made, black ink only should be used, as the colored inks are so transparent that the lines do not show distinctly on the blue prints. In this case make all dimension lines, center lines, and projection lines very fine, as otherwise they will be confused with the full and hidden lines of the object.

The Steam Engine.

A small vertical steam engine will be used as the basis of the following fifteen plates, as the steam engine is probably the commonest example of a machine containing the principal fastenings and details of machine construction.

A Steam Engine is a machine which transforms the pressure and expansive force of steam into work of some kind. The work performed may be the driving

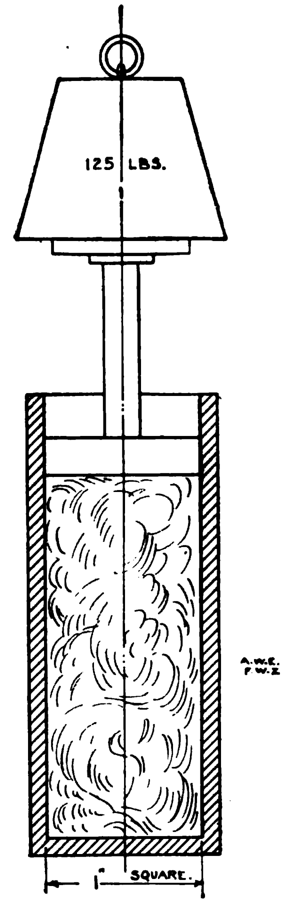


Fig. 5

of a dynamo which generates electricity, the running of an automobile, or the turning of a line shaft which runs all the machines in a factory.

The steam is generated in a closed boiler from which it comes under high pressure, usually about 100 to 125 pounds per square inch—i. e., if a tube of one square inch section, solid at one end and fitted at the other with a movable plug, was filled with this steam at 125 pounds pressure, as in Fig. 5, it would be necessary to place a weight of 125 pounds on the movable plug to keep it from being pushed out by the steam.

This high pressure steam is conducted into the steam chest, see Fig. 6, through a metal pipe, and thence through Port No. 1 to the upper end of the cylinder, where its force is exerted to push the piston to the lower end of the cylinder. Notice that while Port No. 1 places the upper end of the cylinder in connection with the live or high pressure steam, that Port No. 2 places the lower end in connection with the exhaust pipe through which the used or exhausted steam passes out into the atmosphere. As soon as the piston reaches the lower end of the cylinder these conditions are reversed by the raising of the valve, as is shown in Fig. 7, and the piston is forced upward by the live steam admitted to the cylinder through Port No. 2. This cycle of operations, repeated rapidly and regularly (from 50 to 500 times per minute), gives the piston reciprocating, or back and forth motion, and this is transmitted to the crosshead by means of the piston rod. Sometimes this reciprocating motion is all that is necessary, as in the smaller types of steam pumps, but usually it is circular or rotary motion that is wanted, as in the turning of a circular saw, an exhaust fan, or the drivers of a locomotive. In this case, as shown in Fig. 6, one end of a connecting rod is attached to the crosshead, and the other end to a crank which turns the main shaft of the engine. This is the usual method of changing reciprocating into rotary motion, or vice versa.

An engine is usually rated by the amount of Horse Power that it will develop. An engine of one horse power (H. P.) being capable of doing about the same amount of work as one horse; a two horse power engine, two horses, and so on. In exact figures, one horse power is equivalent to the work done in raising a weight of 33,000 pounds one foot in one minute, to one pound raised 33,000 feet in the same time, or to any combination of pounds and feet which multiplied together will give 33,000.

The horse power of an engine can be determined if the following data are known:

M. E. P.=the average steam pressure in the cylinder during one stroke of the piston, or as it is called the Mean Effective Pressure.

L=the length of the stroke, or the distance the piston travels in either direction, in feet.

N=the number of strokes of the piston per minute or its equivalent, twice the number of revolutions of the flywheel per minute.

A=the area of one face of the piston in square inches, or its equivalent, the sectional area of the cylinder.

$$\text{Then H. P.} = \frac{\text{M. E. P.} \times L \times N \times A}{33000} \qquad 15.$$

By studying this formula it is easily seen that the greater any of the terms in the numerator are made, the greater the H. P. of the engine becomes. That is,

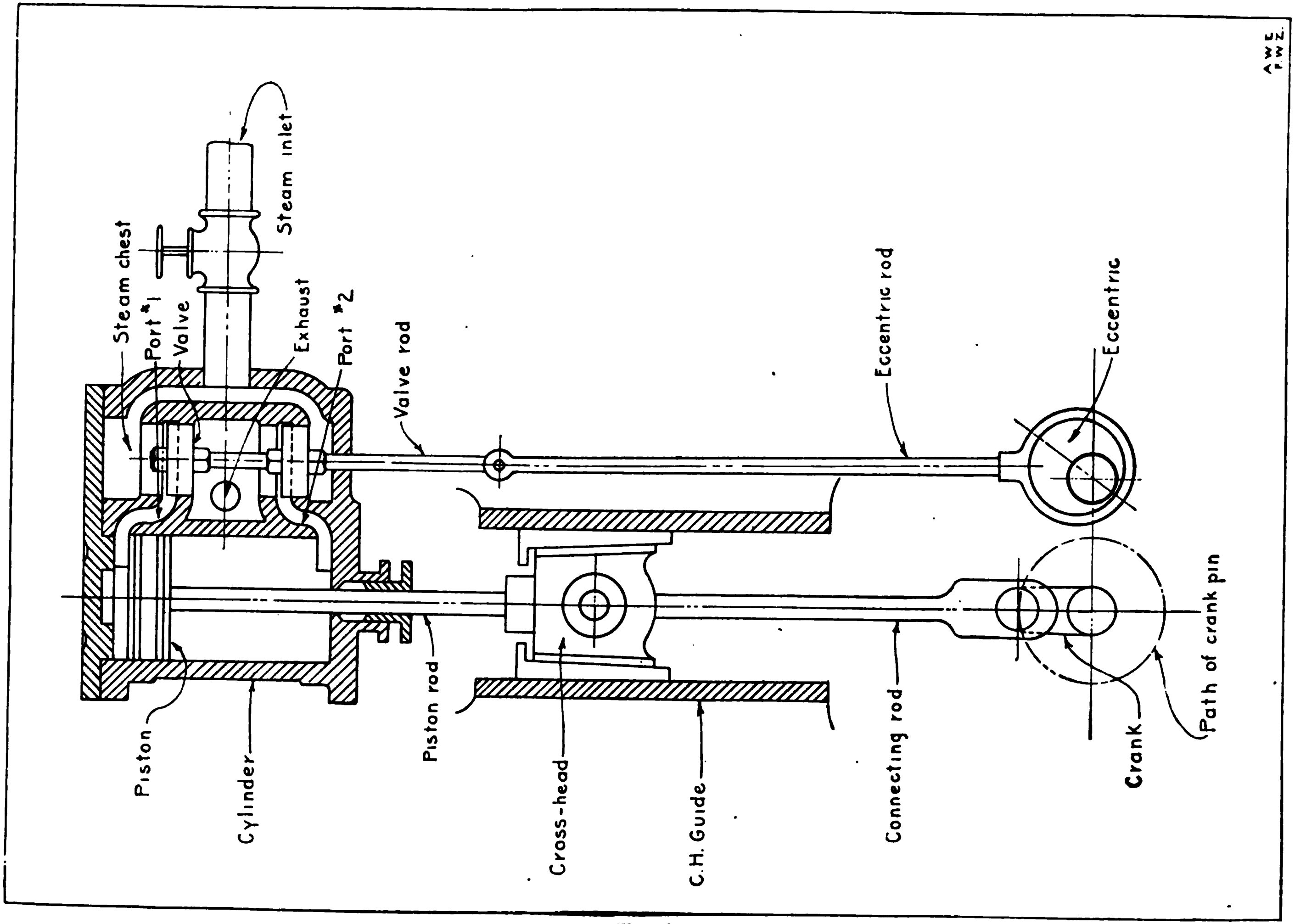

Steam inlet
Steam chest
Port #1
Valve
Exhaust
Port #2
Valve rod
Eccentric rod
Eccentric
Piston
Cylinder
Piston rod
Cross-head
C.H. Guide
Connecting rod
Crank
Path of crank pin
A.W.E.
F.W.Z.

Fig. 6

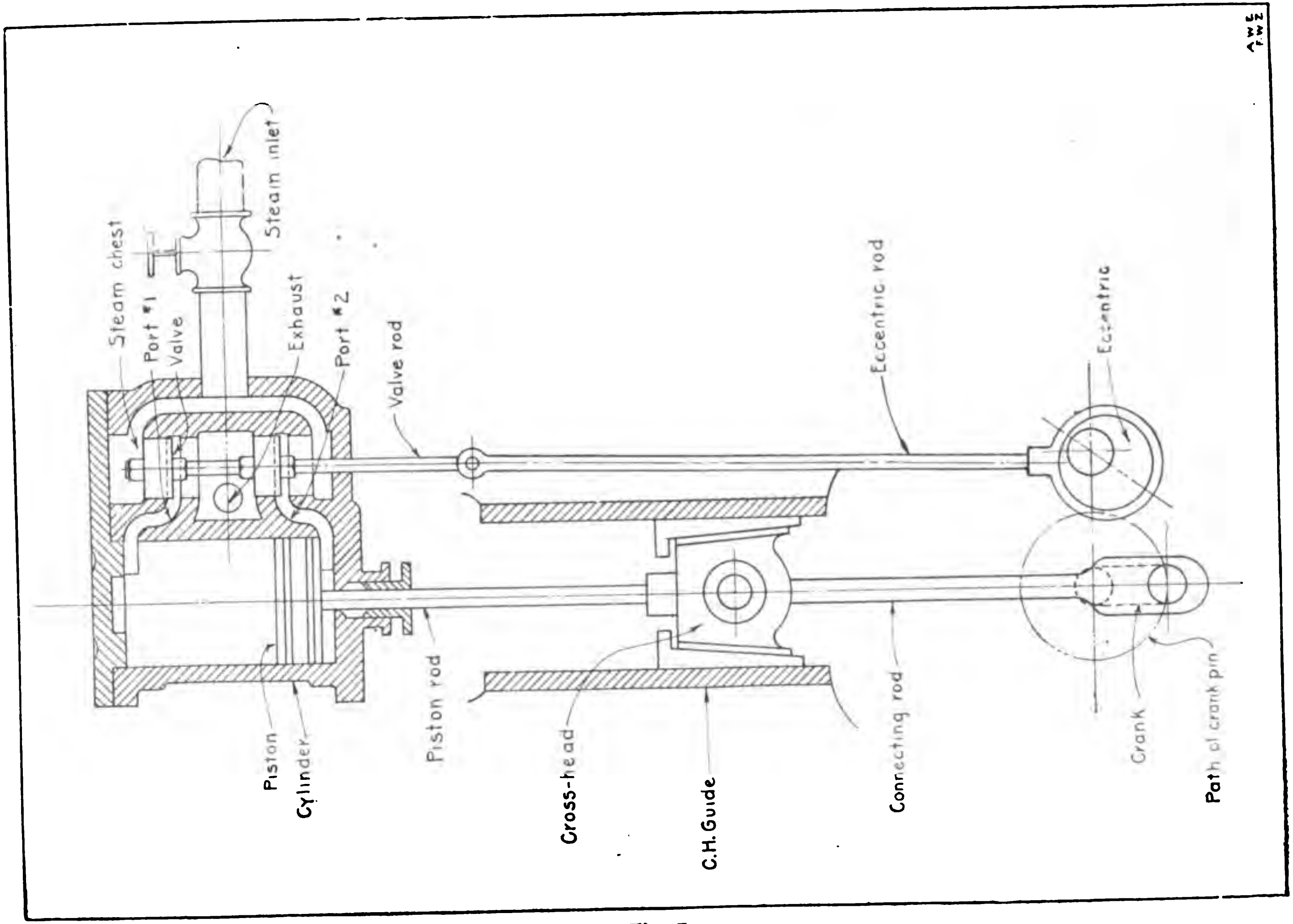

Steam chest
Port #1
Valve
Exhaust
Port #2
Steam inlet
Valve rod
Eccentric rod
Eccentric
Piston
Cylinder
Piston rod
Cross-head
C.H.Guide
Connecting rod
Crank
Path of crank pin

Fig. 7

an engine is made more powerful if the pressure of the steam is increased, if the length of the stroke is increased, if the speed is made greater, or if the diameter of the cylinder and piston is enlarged.

Problem.—What is the H. P. of an engine in which M. E. P=75 pounds, L=12″, N=450, and A=78.54 sq. inches?

In designing an engine certain definite limitations of horse power, size and speed have to be known or decided on. Let it be assumed, then, that a small engine is desired of about 7 H. P., running at the comparatively low speed of 200 revolutions per minute, that the mean effective pressure of the steam be estimated at 60 pounds per square inch, with a maximum steam pressure of 125 pounds, and that the length of the stroke be 6″. By substituting these values in Formula 15, it is found that all are known except A, the area of the piston.

$$\text{Then } 7=\frac{60\times\frac{1}{2}\times400\times A}{33000}$$

$$\text{Transforming } A=\frac{7\times33000}{60\times\frac{1}{2}\times400}$$

Solving, A=19.25 square inches.

19.25 square inches, therefore, should be the area of the piston, but as it is the diameter that is needed for the drawing, this must be determined from the known relation between the area and the radius of a circle, $A=3.1416\times R^2$, where A=area, and R=radius of circle. The diameter, by this means, is found to be a trifle less than 5″. What is the exact figure? For facility of manufacture the nearest whole number, 5″, would be taken as the diameter.

Having decided on these dimensions which determine the size of the interior of the cylinder, the designer would then probably build up systematically a sectional General Drawing of the engine on a scale of one-half or one-fourth size, beginning with the piston and cylinder, and determining the dimensions of each part in turn from the results of his experience, from general practice and from mathematical formulae. For this particular engine, Plate XIV shows such a sectional general drawing, or drawing of the engine with all its parts assembled in their correct relation to each other.

It is evident from an inspection of Plate XIV that such a problem would be too difficult for the beginner in machine design, and so it will be assumed that the general drawings have been completed by a competent designer, and that it is now required to make a complete set of Detail Drawings, showing each separate piece from these general drawings.

The dimensions of the border lines of the plates will be the same as heretofore, 12″x17″.

PLATE II.

Details of Piston and Piston Rod.

On Plate II are shown free-hand mechanical sketches of the details which are to be drawn on this sheet. Each pupil is expected to use his judgment in placing the exercises, so that the complete drawing will have a well-balanced appearance. A space should be reserved in the lower right hand corner for the main title.

Exercise 1.—Make a detail drawing of a cast iron piston for a 5″x6″ vertical engine. Scale, half size. Draw end view and vertical section.

The piston must conform to the following conditions:

1. It must be strong enough to withstand the maximum pressure of the steam without being too heavy. As the diameter of the piston was figured to be 5″, the area would be 19.6 square inches, and as the steam pressure is to be 125 pounds per square inch, the total pressure on the piston would be 19.6x125, or 2,450 pounds, almost 1¼ tons.

2. It must form a tight joint with the cylinder, or the steam would leak to the other side of the piston, reducing the difference in pressure between the two sides, thus causing the engine to run poorly or not at all. This is accomplished by turning grooves on the piston and fitting in spring piston rings which press against the sides of the cylinder. Plate XIV shows these rings in position.

The piston is cast hollow in order to make it as light as possible. It is extremely difficult to make a hollow casting without any opening, so two circular holes are left which are afterward threaded and closed with plugs as shown.

In addition to a complete set of dimensions, each detail drawing should give the following data in the form of notes:

1. The name of the part detailed. 2. The material of which it is to be made, in this case cast iron (C. I.). 3. The number which are needed to complete one engine, or whatever machine is being drawn. 4. The surfaces which are to be finished smooth in the machine shop all marked "finish" or "F" or "f." If a surface is not marked finish in any way, it is usually taken for granted that the designer intended it to be left rough just as it came from the foundry.

Exercise 2.—Make a detail drawing, two views, of a cast iron piston ring, designed to fit the above piston. Scale, half size.

Piston rings are cast and turned solid and then cut apart. Notice the method of making the joint steam tight. The ring is made ⅛″ larger in diameter than the inside of the cylinder, so that when it is sprung over the piston and forced into place it will expand against the walls of the cylinder and make a steam tight joint. The thickest part must be a little less than the depth of the groove in the piston, and the width should be exactly the same as the width of that groove. Two centers are used in drawing the inside and outside diameters, in order to make the ring taper toward the joint. The distance between these centers is known as the eccentricity. A note should show that two rings are required as there are two grooves in the piston.

Exercise 3.—Make a detail drawing for a cast iron screw plug, having 16 threads per inch, for above piston. Scale, full size.

A note should show the number of threads (16) which should agree with a similar note on the piston. In general all bolts, nuts, screws, etc., should be marked with the number of threads per inch. If it is not given it is understood to be United States standard, as per Table III for the given diameter. Notice that the number of threads in this case is "special."

Exercise 4.—Make a detail drawing, two views, of a steel piston rod for above engine. Scale, half size.

The piston rod must conform to the following conditions:

1. It must be firmly attached to the piston and crosshead, for when the steam is forcing the piston up there is a pressure of nearly 1¼ tons tending to push these parts from the rod. This is accomplished by making the diameter of the part of the rod that fits in the piston a trifle large, and forcing it into

place in a hydraulic press (see note "Pressed in") and then locking with a nut, and by screwing the other end into the crosshead and locking with a nut.

2. It must be long enough, so that when the piston is at the upper end of the stroke there will be no danger of the crosshead striking any part of the cylinder. This was determined on the general drawing Plate XIV, by laying out all the parts accurately to scale and then measuring the required length.

3. The diameter must be great enough to prevent any danger of breaking under the maximum steam pressure. This can be determined from the following formula:

Let a=least area of the rod under maximum strain;
=area at the root of the right hand threads;
St=tensile strength of steel, from Table I;
F=factor of safety, which in this case will be taken twice the highest value given in the table, on account of the great strain that piston rods have to withstand;
P=maximum steam pressure=125 pounds;
A=area of piston=19.6 square inches.

$$\text{Then } a = \frac{F \times P \times A}{St.} \qquad 16.$$

$$\text{Substituting, } a = \frac{16 \times 125 \times 19.6}{60000}$$

Solving, a=.653 square inches.

By referring to Table III, it is seen that the nearest size larger than this in the column marked area at root of the threads is .694 belonging to a 1⅛″ bolt, which is the required dimension. The shoulder at "A" is to prevent the piston from being pushed down on the rod by the steam pressure. All threads are standard, and should be drawn according to the convention shown at (c) Fig. 4.

Exercise 5.—Make a drawing of a 1″ steel nut, two views, designed to lock the piston on the piston rod. Scale, full size.

The only variation from standard is that the height of the head is made ¾ D, instead of D. All other dimensions are to be taken from Table III and Exercise 6, Plate I. The curves all have the same radius as the curves of a 1″ standard nut.

Exercise 6.—Make a detail drawing of a 1⅛″ special brass lock nut above piston rod. Scale, full size. Make half sectional elevation and end view.

This nut is made from brass to prevent it from rusting on to the piston rod. The projection is to cover the end of the threads on the rod. The dimension "A" is to be made equal to the diameter of the piston rod. Other dimensions as per Plate I. Exercise 6.

Title.—See Introduction and Standard Alphabets for directions as to making title. It would be better to design a standard form of title, have it accepted by the instructor, and adhere to it as closely as possible throughout this set of detail drawings.

Bill of Material or Table of Engine Details.—On a separate sheet of drawing paper, a table should now be started which eventually will contain the name, number, material, etc., as per appended sample, of every piece which goes into the construction of the engine. As soon as each detail sheet is finished the parts included on that sheet should be added to this table.

Bill of Material for 5″x6″ Vertical Engine.

Exercise	Plate	Name	Number Required	Material
1	II	Piston	1	Cast Iron
2	II	Piston Ring	2	Cast Iron
3	II	Screw Plug	2	Cast Iron
4	II	Piston Rod	1	Steel Rod
5	II	Nut for Piston Rod	1	Steel
6	II	Special P. R. Nut	1	Cast Brass

About 60 lines, ¼″ apart, will be needed for the items. One of the Standard Alphabets is to be used in designing the title, which should be worked out in harmony with the standard titles on the drawings. Headings of columns, 3/16″ skeleton capitals. Items, ⅛″ skeleton capitals.

PLATE III.

Cylinder Cover and Stuffing Box Glands.

Plate III shows free-hand sketches of the parts from which the finished mechanical drawings are to be made.

Exercise 7.—Make a detail drawing (plan and vertical section) of a cast iron cylinder cover for the 5″x6″ vertical engine. Scale, half size.

The cylinder cover must be detachable so that the piston may be put in place and adjusted occasionally, it must be fitted to the cylinder accurately, so that the joint will be steam tight, and it must be fastened to the cylinder securely, or the pressure of the steam will tear it off. The fastening is usually accomplished by making a flange or projection around the upper end of the cylinder, and bolting the cover to it. Sometimes instead of an ordinary machine bolt, a stud bolt having a screw thread in place of a head is used, as in this case (see Exercise 8). The holes should be drilled 1/16″ larger than the diameter of the stud bolts, and they should all be the same distance from the edge of the cover. The position of the holes should be accurately dimensioned, and these measurements must agree with the dimensions on the end of the cylinder.

Exercise 8.—Make a detail drawing of a steel stud bolt and nut to be used in fastening the cover to the cylinder. Make two views of each part. Scale, full size.

The bolts must be large enough in diameter at the bottom of the threads to withstand the maximum steam pressure, plus an allowance for tightening the nut in making a steam tight joint. For method of figuring diameter see Piston Rod. The length of the part of the thread that is screwed into the cylinder (A) should be 1¼ times the diameter of the bolt. B should be ¼″ less than the thickness of the cylinder cover. C should be made of such a size that the bolt will extend ⅛″ above the top of the nut when it is in position. D, of course, must equal A+B+C. The number of threads per inch and the size of the nut should be taken from the table given under Plate I.

Exercise 9.—Make a detail drawing of a brass packing or stuffing box gland for the valve rod of a 5″x6″ vertical engine. Make an end view and sectional elevation. Scale, full size.

It is evident that unless some means are taken to prevent it, steam will leak out of the cylinder and steam chest around the valve and piston rods. This leakage is prevented in the same way that water is prevented from leaking past the valve handle of a faucet, by making a cup-shaped projection or stuffing

box around the rod, and filling it with packing, which is squeezed tightly against the rod by screwing up the gland. See Plates XIV and XV for sections of the complete stuffing box. Notice the glands on water faucets which are similar in shape to the one shown here.

The dimensions are given in terms of the diameter (D) which equals ⅝″. These given ratio dimensions can be used for rods up to one inch in diameter. Make the section lining to show the material, brass.

Exercise 10.—Draw a plan and half sectional elevation of a brass packing gland for the piston rod of a 5″x6″ vertical engine. Scale, full size.

This form of gland is the one usually used with large rods and high pressures. It can be seen on most locomotive and stationary engines. It is held in place and forced down on the packing by tightening the nuts of the stud bolts, Exercise 11. The outer curve is an ellipse and may be drawn by a method shown on the geometrical plates of the first year for constructing an ellipse having the length of the axes given.

Exercise 11.—Draw two views of the steel stud bolt and nut for the packing gland of Exercise 10. Scale, full size.

E equals 1¼ times the diameter of the stud bolt, the same as A of Exercise 8. Other dimensions as in sketch and table for bolts and nuts.

For title see previous instructions and sample title shown on Plate III. After the plate has been inked or traced, add these details to the Bill of Material started under Plate II, being careful to specify the correct number of each part required for one complete engine. If in doubt as to the number of parts, consult the general drawings given on Plates XIV, XV and XVI.

PLATE IV.

The Cylinder.

Exercise 12.—Make a detail drawing of a cylinder suitable for a 5″x6″ vertical steam engine. Draw a sectional elevation, a sectional side view and a half sectional plan. Scale, half size.

Plate IV shows to a small scale the cylinder completely drawn as specified in the statement.

What is called the cylinder of an engine usually consists of the cylinder proper (marked A in the drawing) in which the live steam pushes the piston back and forth as explained on Page 61, and the steam chest (S) connected together by the ports (P). The steam chest in this case consists of the live steam chambers (B_1 and B_2) connected by the passage of (C) with each other and with the steam inlet pipe, the exhaust chamber (D) from which the steam passes out through the exhaust pipe to the open air, and the valve chambers (E_1 and E_2) in which the valves separate the live from the exhaust steam, as shown on Plate XV. F and G are the stuffing boxes described under Exercise 9.

On account of their complicated structure, it would be practically impossible to form engine cylinders from wrought iron or steel, so they are almost universally made from cast iron.

The length of the cylinder inside when the cover (Exercise 7) is in place must be equal to the length of the stroke, plus the thickness of the piston, plus a certain amount of necessary clearance at each end. This clearance should be as small as practicable, in this case ⅛″, as it is evident that an amount of steam is wasted at each stroke equal to the combined volumes of the port and the clearance. From above data

figure out this inside dimension and place it on the drawing. The diameter of the cylinder must be equal to the diameter of the piston, and the walls thick enough to withstand the bursting pressure of the steam. The steam passages must be large enough to carry a sufficient amount of steam to fill the cylinder during the brief interval that it takes for one stroke of the piston, and care should be taken that the sectional area of each passage is at least as great as the area of the steam pipe. As the steam expands in volume when it gives up its pressure to the piston, the exhaust pipe must be made larger than the inlet pipe.

The spacing (K, etc.) of the tapped holes on the upper end of the cylinder should agree exactly with the spacing of those on the cylinder cover, Exercise 7. The tapped holes at the lower end are to fasten the cylinder to the engine frame. Mark the diameter of these holes and the number of threads per inch; see Table III on blots and nuts, and Sheet III. The spacing (H) and size of the holes on the stuffing box should agree with those of the gland and stud drawn on Plate III. The sizes of the openings for the inlet and exhaust pipes are the same as the outside diameter of the pipes, given in Table II, the sizes given in the notes being the inside diameters, by which pipes are generally specified.

Notice that wherever possible the lines of the cylinder, and, for that matter, of all castings, are curves. A rounded casting is much stronger than a flat or square one. The inside corners of castings, as at L, are usually rounded into a small curve or fillet, which makes the metal less liable to crack or break than with the sharp corner. The fillets vary in radius from ⅛″ to ½″, the dimension usually not being given on the drawing. Use the radius in each case which gives the best looking curve.

On account of the position of the views, it will be necessary to place the title in the upper left hand corner instead of in the usual place.

PLATE V.

Crosshead Details.

The crosshead joins the piston rod to the connecting rod, and at the same time by sliding back and forth in the guides attached to the frame (as shown in Figs. 6 and 7, and on Plate XIV), it prevents the piston rod from being bent by the sidewise thrust of the connecting rod.

The crosshead must conform to the following requirements:

1. It must be securely attached to the piston rod. This is usually accomplished by screwing the piston rod into the crosshead and locking with a nut to prevent the rod from working loose.

2. It must be securely fastened to the connecting rod in such a way that the rod is free to swing to a limited extent about an axis at right angles to the piston rod. This can be done by drilling holes through the end of the connecting rod and the crosshead, and inserting a pin called a crosshead pin.

3. It must have rubbing surfaces made to fit the guides attached to the frame. These shapes are determined in various ways, but a common method is to bore out the inside of the frame parallel to the cylinder walls, and to make the crosshead in the form of a cylinder with two sides sliced off parallel to its axis and turned to exactly fit the hole bored in the frame. The rubbing surfaces in contact must have an area suffi-

cient to prevent them from wearing away too rapidly, and must have some easy means of lubrication.

4. There must be some method of taking up the wear—i. e., of increasing the size of the crosshead as it wears down from its constant rubbing on the guides. This is done by turning the rubbing surfaces on separate blocks from the main crosshead, which are capable of being adjusted for a short distance on a tapered surface, as shown in Exercise 14.

Plate V shows sketches of the separate details of such an adjustable crosshead.

Exercise 13.—Draw three views (plan and front and side elevations) of a cast steel crosshead frame suitable for a 5″x6″ vertical engine. Scale, full size.

The size of the large tapped hole must agree with the size of the piston rod and nut. The small tapped holes are for the studs used in adjusting the slide shoes. The other holes are for the crosshead pin. The excess metal around these holes is known as a boss and is added for strength, and also to facilitate finishing or smoothing the piece in the machine shop. The note "Taper 1 in 20" means that if the slanting surface were extended for 20″, one end of it would be 1″ further out from the center line than the other. The slope may be determined by laying out a 5″ horizontal line, erecting a ¼″ perpendicular at one end of it, and joining the ends of these lines. This hypotenuse will have the required slant.

Exercise 14.—Make a detail drawing (three views) of a brass slide shoe for above crosshead from the given sketch. Scale, full size.

The radius of the rubbing surface (3″) must agree with the radius of the hole bored in the frame for the guides. The taper must agree with the taper of the crosshead frame, and the groove in this tapered surface is to fit over the corresponding projection on the crosshead frame, with which it must agree in size. The adjusting stud (Exercise 16) passes through the slot in the projecting shelf, and by means of the nuts moves the shoe on the tapered surface, thus increasing or diminishing the total diameter of the crosshead in order to fit the guides.

Exercise 15.—Make a full size detail drawing, two views, of the steel crosshead pin, nut and washer shown in the sketch.

The length and diameters of the pin must agree with the corresponding dimensions of the crosshead. The nut and washer are to prevent the pin from working out of place, and also to hold the shoulder (A) firmly against one of the bosses of the crosshead in order to keep the pin from turning. The threaded part is made smaller in diameter, as it is not subjected to any special strain. The part of the pin marked with the two crossed lines (the bearing surface) is the part on which the connecting rod swings back and forth with each revolution of the flywheel. If this bearing were not lubricated it would soon become heated by the friction, and expand until the connecting rod could not turn. Therefore, holes are drilled, as shown, through the center of the pin, and an oil cup attached which supplies a constant stream of oil to the rubbing surfaces. As the full force of the steam in the cylinder is exerted on the pin, its diameter must be great enough to withstand this shearing stress. See Table I for shearing strength of metals.

Exercise 16.—Make a detail drawing of the steel adjusting studs and nuts required for the crosshead of the 5″x6″ vertical engine. Make two views of each different piece. Scale, full size. No sketch given.

The stud is to be 3″ long, and of the proper diameter to fit the tapped holes in the crosshead. The stud is to be threaded throughout its whole length with a standard thread; two required.

Two standard steel nuts are needed for each stud. See Table III for dimensions.

Check the plate carefully to see that all necessary notes, sub-titles, finish marks and main title are included. Add all parts to the Bill of Material as usual.

PLATE VI.

Connecting Rod.

A connecting rod is that part of an engine which connects the reciprocating crosshead with the rotating crank shaft. One end, therefore, works back and forth in a straight line, while the other end revolves in a circle.

A well-designed rod must conform to the following requirements.

1. It must be strong enough to withstand the total pressure of the steam; in this case 2,500 pounds. This means that at right angles to the pressure, every possible cross section of all pieces that have to sustain the pressure must have a certain minimum area which has been calculated as sufficient to withstand the stress. This minimum cross section must be a little greater than that of the piston rod, on account of the angular position of the connecting rod at mid stroke, see Plate XIV. A common rule is to make the diameter at the end of the rod (C) equal to 1.1 times the diameter of the piston rod. The diameter at the middle of the rod (D) is made somewhat larger to keep the rod from buckling, and may be made equal to 1.2 times the diameter of the piston rod. The length between centers for small engines should be from 2½ to 3 times the stroke of the piston.

2. The crosshead end must be securely attached to the crosshead pin in such a way as to be free to rotate through the angle required by the revolution of the crank, and must have a sufficient bearing surface on the pin to prevent undue wear and heating from friction.

3. The crank end must be securely attached to, and free to rotate on the crank shaft, where it must also have a large enough bearing surface to prevent excessive wear and heating. This rubbing surface must be considerably greater than at the crosshead end. The crank end must also be so constructed that it can be detached from the crank.

4. There must be some method of taking up the wear occasioned by the constant rubbing of the bearing surfaces. Two methods are shown. At the crosshead end a hole is drilled in the end of the connecting rod, into which a bronze bushing or hollow bronze cylinder (Exercise 19) is pressed, which can be replaced when it wears out. At the crank end is shown a split bronze box (Exercise 21) the pieces of which can be pressed together gradually as the hole wears larger by driving down the cotter (Exercise 23) which draws the strap (Exercise 20) up over the stub end of the rod. This same mechanism permits the rod to be disconnected from the shaft.

Plate VI shows a complete general drawing of the rod, constructed to a small scale. This assembled drawing should be made for the first exercise and then detailed drawings should be made of each separate piece, sizes being determined from the general drawing. The separate pieces of the general drawing are numbered to agree with the exercises.

Exercise 17.—Make a complete assembled drawing of the connecting rod for a 5″x6″ vertical steam engine. Scale, half size. Draw plan and front elevation.

Axis of top view, 1⅜″ D. Axis of front view, 4¼″ D.

At "A" and "B" there will be curves formed by the intersection of the curved surface with the flat sides of the stub. These should be constructed with the help of a temporary end view having concentric circles which show the positions of the curve for equal spaces on the front view. The longitudinal hole through the stub is for the purpose of oiling the bearing surfaces of the box and crank shaft. It is intended that a small oil cup (Exercise 31) shall be screwed into the upper tapped hole. Only the main dimensions should be put on this general drawing. Reserve the smaller dimensions for the details.

Exercise 18.—Make three views of the rod part of the above connecting rod. Material steel. Scale, half size. Put in all necessary dimensions, notes and finish marks.

Axis of top view, 6⅜″ D. Of front view, 7⅞″ D. Draw to the right as far as possible.

Construct curves at "A" and "B" as on the assembled drawing. The directions for C and D are given under the first requirement of a connecting rod. The dimension E must be the same as the distance between the bosses of the crosshead. The length is to be figured from the detailed dimensions. One required. Finish all over.

Exercise 19.—Make a detail drawing (two views) of the bronze bushing for the crosshead end of above connecting rod. Scale, half size.

Draw in lower left hand corner with axis of both views 10½″ D. The bushing and the box of Exercise 21 are made of bronze, because it has been found in practice that there is less friction in a bearing when one of the rubbing surfaces is made of this metal. One required. Finish all over.

Exercise 20.—Draw three views of the steel strap for the crank end of the above connecting rod. Scale, half size.

Place at the left between the bushing and the general drawing. Any cross section through the two sides of the strap must be equal to the area of the rod at C. The ends of the strap are made thicker to compensate for the metal cut away in forming the slots. One required. Finish all over.

Exercise 21.—Draw two views of the bronze box in the crank end of the above connecting rod. Scale, half size.

Place to the right of the bushing using the same axis. In order that the hole may be perfectly true, the two parts are cast in one piece, finished to size in the machine shop and then sawed apart. The metal taken out by the saw allows the parts to be pushed closer together, as the hole wears larger from the friction with the crank pin. One required. Finish all over.

Exercise 22.—Make a detail drawing of the ⅜″x1″ round point steel set screw, used to keep the cotter of above connecting rod from slipping. Scale, half size. Place between the bronze box and the title. One required.

Set screws are small machine screws which, instead of clamping pieces rigidly together, are used to hold machine parts in place by being set or pressed

against them. As the head is used only for turning the screw into place, it is usually made much smaller than the standard bolt head, as shown in Fig. 8 at (a), or dispensed with entirely as at (b). The height of the head (H), and the distance across the flats (J) should be made equal to the diameter of the screw. The number of threads per inch should be the same as that for ordinary bolts given in Table III. A round point set screw is shown at (a), a cone point at (b), and a cup point at (c).

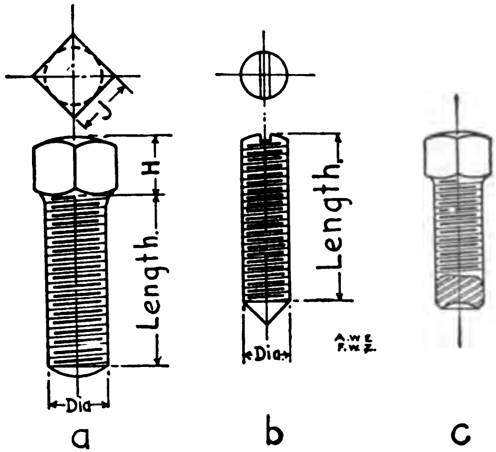


Fig. 8

Exercise 23.—Draw two views of a steel cotter for above connecting rod. Scale, half size.

This exercise with the next one is to be placed in the upper right hand corner of the plate.

A cotter is a wedge-shaped key which is used to fasten two machine parts together that require slight adjustment in relation to each other. It may be used with or without the gib shown here, but if used without the gib it must be made proportionately wider. As the full force of the steam pressure is acting to shear the gib and cotter at the joints between the rod and the strap, their combined cross section at these points must be to the least cross section of the rod as the shearing strength of the metal in the gib and cotter is to the tensile or compressive strength of the metal in the rod. (See strength of material, Table I.) For explanation of taper see crosshead, Exercise 13. One required. Finish all over.

Exercise 24.—Draw two views of a steel gib for above connecting rod. Scale, half size.

The taper must be the reverse of that in the cotter. The thickness must be the same as the cotter. One required. Finish all over.

Place main title in lower right hand corner. Add these details to the Bill of Material.

PLATE VII.

General Drawing of Crosshead.

A general drawing of the connecting rod was given on Plate VI, from which the details were worked out. Here the work will be just the reverse, that is, the assembled or general drawing will be built up from the details given on previous plates, and from the assembled drawings of the whole engine shown on Plates XIV and XV.

Exercise 25.—Make a general drawing of the crosshead for a 5″x6″ vertical engine, showing one end of the connecting rod and one end of the piston rod and nut in their correct position. Draw two half sectional views, which are to be taken at right angles to the axis of the engine. Scale, ¾″=1″.

Main axes to be horizontal. That of top view 2½″ D. Axis of front view, 7¼″ D. Vertical axis through crosshead pin, 7½″ R.

Using Plate V, draw the two views of the crosshead frame in their correct position with respect to the axes given above. The crosshead pin should then be put in place, care being taken to have the washer and nut on the side of the crosshead which has the smaller diameter hole. Then draw the slide shoes in place, setting them in such a position that the diameter of the crosshead will be exactly 6″. The adjusting studs should extend ½″ into the tapped holes in the crosshead frame, with a nut on each side of the shelf pro-

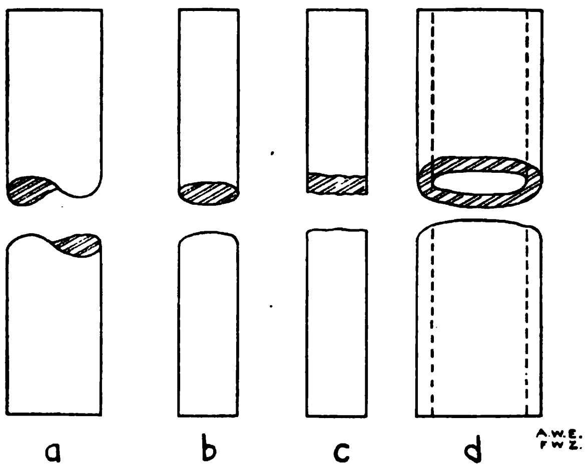


Fig. 9

jecting from the slide shoe. Place the connecting rod in position on the crosshead pin, setting it at the upper limit of swing determined by the crank pin path. See Plate XIV. The piston rod (see Plate II) should be drawn so that its end comes flush, or even, with the inside of the crosshead frame. The special piston rod nut (Exercise 6) should be placed on the piston rod, tight against the crosshead. As only one end of the piston and connecting rod are represented, the ends should be finished off with the conventional break, Fig. 9 (a). The breaks shown in the figure are intended to give some idea of the form of a piece which is only partly drawn. The oil cup (Exercise 31) should be drawn in place on the crosshead pin, using a 45° elbow and nipple (Exercise 32) for the connections. No dimensions or notes should be placed on this drawing. The following statement should be made into a title, consistent in design with the titles of the previous drawings, and placed in the lower right hand corner of the plate. General drawing of crosshead, 5″x6″ vertical engine, name of school, scale ¾″=1″, date, drawn by, checked by, approved by.

PLATE VIII.

The Crank Shaft.

The crank shaft receives the rotating motion from the end of the connecting rod and transmits it to the pulley, flywheel and eccentric. The shaft is prevented from making any movement excepting that of rotation by being placed in two bearings attached rigidly to the engine frame (see Plate X). The part of the shaft fitting in these bearings is so marked on the sketch. It is usually formed under the steam hammer in the blacksmith shop, and then finished in the machine shop.

Exercise 26.—Make a detail drawing of the forged steel crank shaft shown in the sketch on Plate VIII. Draw front and end views. Scale, ⅜″=1″.

The diameter of the shaft must be great enough to resist the torsional or twisting moment produced by the maximum pressure of the connecting rod on the crank pin, as well as large enough to resist the bending stress caused by the rod, the pulley and the flywheel. The diameter (G) of the crank pin must equal the bore of the bronze box of the connecting rod. The length must be the sum of the following items: The length (A) of the crank pin, which must equal the length of the box of the connecting rod; the thickness of the two arms or cranks including the bosses; the length (B) of the two bearing surfaces which must be equal to the bearings on the frame (Plate X), and on small engines these are usually made twice the diameter of the shaft; the lengths (C, D and E) respectively of the hubs of the eccentric (Plate XI), the pulley (Plate IX), and the flywheel. Having determined these dimensions, add them together and check with the total length of shaft as given, less the bevel at each end. The radius of the crank pin circle (F) must be one-half the travel of the piston.

The ends of the shaft over which the flywheel and the pulley fit are turned down to a smaller diameter, in order to give a shoulder for these parts to fit against, and are provided with a long key way or groove, which must be exactly as wide and one-half as deep as the key itself. For dimensions see Keys, Exercises 28 and 29.

The Flywheel.

As the pressure of the connecting rod on the crank varies greatly during every revolution of the shaft, and as this pressure is more efficient in some positions of the crank than in others, the speed of the engine will have large fluctuations unless means are taken to reduce them. This duty is performed by the flywheel. A revolving flywheel has stored in it a certain amount of energy, which depends on the speed of rotation, and on the combined effect of the weight and the distribution of this weight in the wheel. Other conditions being the same, the most effective portion of a flywheel is the rim, as this part has the highest velocity. Therefore as much of the weight as possible should be placed in the rim.

Exercise 27.—Make a detail drawing of the cast iron flywheel for a 5″x6″ vertical engine. Scale, 5/16″=1″. Make a half sectional plan, and one-half of the front elevation.

Only one-half of the front view is shown, partly because the details of the drawing would be too small to show up well if it were complete, and partly to save time. The scheme of only drawing a portion of an object can always be used when the object is symmetrical about some center line. The diameter (A) of the hole bored through the hub must equal the diameter of the end of the shaft. The diameter of the hub should be twice the diameter of the hole, which is the ordinary rule for hubs of small diameter —i. e.:

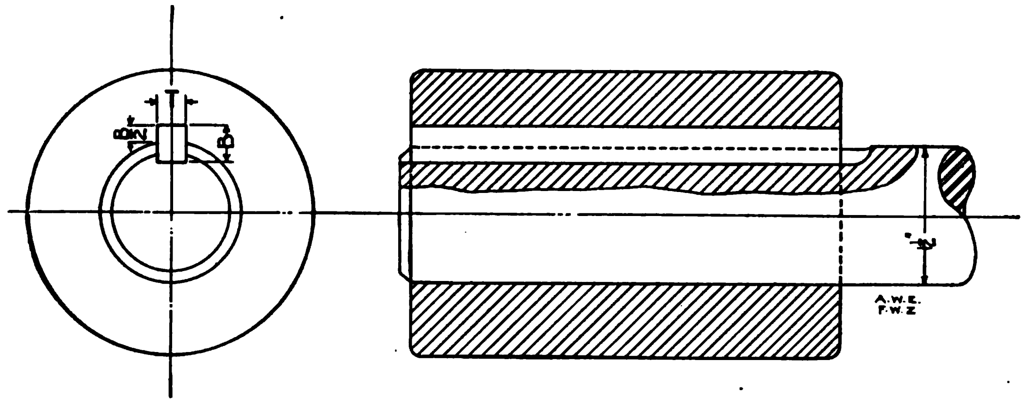
$$B=2A \qquad 17.$$

Where B=diameter of hub;
A=diameter of hole through hub.

The section of the spoke is an ellipse, and can be constructed by the method given on one of the First Year plates. It is the usual custom on drawings to indicate the form of a spoke by a section on the elevation of the spoke, as shown.

The lugs and the holes drilled through the two opposite arms are to hold the governing mechanism. For dimensions of key way see next problem.

Fig. 10



Keys.

Keys are strips of metal, usually rectangular in cross section, which are used to securely fasten pulleys, couplings, cranks, etc., on to shafts in such a manner that they will rotate with the shaft.

Several different methods have been devised for proportioning keys, the following adopted by William Sellers & Co. being one of the best. See Figure 10, in which D=diameter of shaft, B=width of key, and T= thickness of key.

TABLE IV.
Proportions of Keys.

D	B	T
1¼ to 1¾ inches	⅜ inch	$\frac{5}{16}$ inch
1⅞ to 2¼ "	½ "	$\frac{7}{16}$ "
2⅜ to 2⅝ "	⅝ "	$\frac{9}{16}$ "
2¾ to 3¾ "	¾ "	$\frac{11}{16}$ "
4 to 5 "	⅞ "	$\frac{13}{16}$ "
5½ to 6½ "	1 "	$\frac{15}{16}$ "
6⅝ to 9 "	1⅛ "	$1\frac{1}{16}$ "

From the table it is readily seen that

$T=B-1/16''$. 18.

Exercise 28.—Draw two views of a steel key designed to fasten the flywheel to the shaft of the 5″x6″ vertical engine. Scale, half size.

Exercise 29.—Make a detail drawing of a steel key designed to fasten the pulley onto the shaft of the 5″x6″ vertical engine. Scale, half size. Draw two views.

The form of these keys is shown in Figure 10. The length should be the same as the length of the keyways in the shaft. The width and thickness should be taken from the values of B and T in the table corresponding to the diameter of the crank shaft. Keys are usually made of steel or wrought iron, and should fit the keyway accurately.

See that all titles, notes, dimensions, and finish marks are included on the drawing, and then add these details to the Bill of Material.

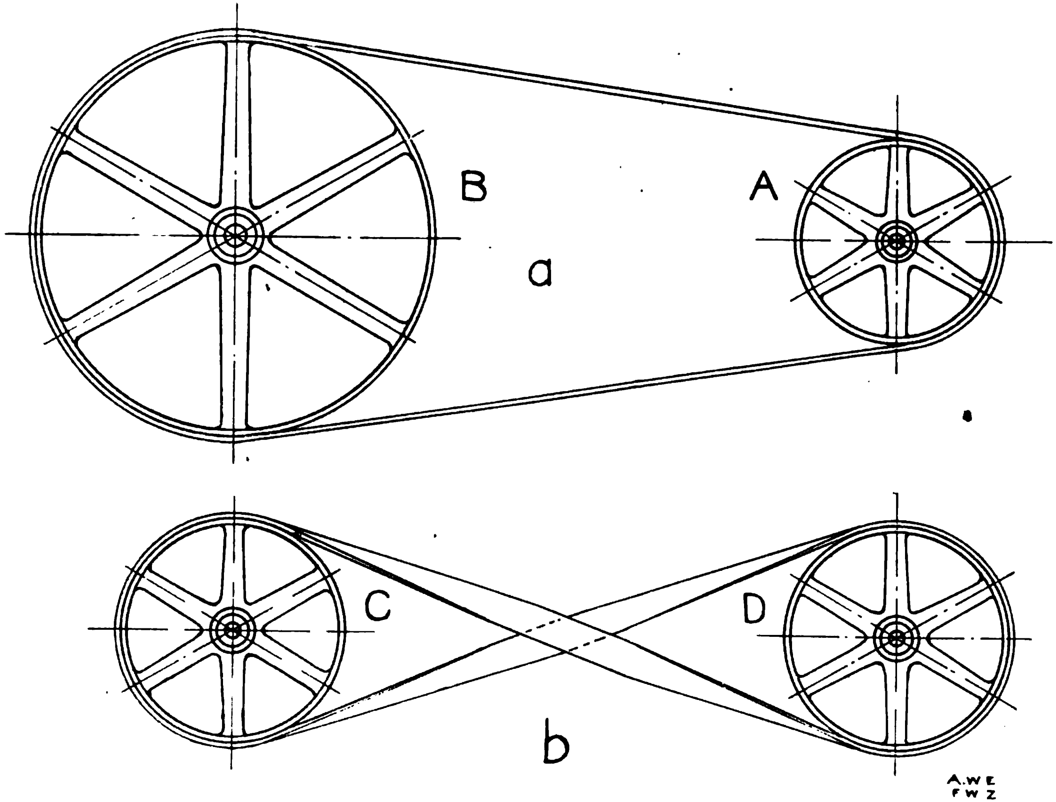


Fig. 11

PLATE IX.

The Pulley.

The usual form of cast iron pulley is shown in the sketch on Plate IX. Pulleys are used in connection with belting to transmit motion from one machine to another. Fig. 11 (a) shows the method of coupling when the direction of motion of the driven pulley (B) is to be the same as that of the driver (A). (b) shows the method of crossing the belts so that the pulleys (C and D) will turn in opposite directions. If the two pulleys are of the same diameter, as at b, their speeds will be equal—i. e., the number of revolutions of each per minute will be the same. If the driver (A) is larger, then the speed of the driven pulley (B) will

be greater than A. If the driver is the smaller, then the reverse will be true. The reason for this is that as all parts of the belt are traveling at the same speed, then the speed of the rims of the two pulleys will be the same. Then if one pulley has a smaller diameter than the other, its length of rim will be correspondingly smaller, and, therefore, it will make a greater number of revolutions per minute. The speeds of two belt connected pulleys are, therefore, to each other inversely as their diameters, radii or circumferences —i. e.:

$$\frac{\text{Speed of A}}{\text{Speed of B}} = \frac{\text{Dia. of B}}{\text{Dia. of A}} = \frac{\text{Rad. of B}}{\text{Rad. of A}} = \frac{\text{Circum. of B}}{\text{Circum. of A}} \qquad 19.$$

Example.—A driving pulley has a diameter of 24″, and runs at 300 revolutions per minute. What is the speed of a driven pulley 16″ in diameter?

The required diameters of pulleys can also be found from the above equation, No. 19.

Exercise 30.—Make a detail drawing of the cast iron pulley for a 5″x6″ vertical engine. Draw a half sectional plan, and one-half of the front elevation. Scale, ⅜″=1″.

The diameter (G) of the hole bored through the hub must equal the diameter of the end of the crank shaft. The directions for diameters (H) of hubs are given under flywheels. The cross section of the spoke is an ellipse. For dimensions of key way see Keys. The width of the belt (E) should be from ¾ to ⅞ of the width of the pulley face. The face of the pulley is crowned—i. e., the diameter of the center of the pulley is greater than the edges, in order to keep the belt from slipping from the pulley. The radius of this crown (J) should be four times the width of the face of the pulley.

Pulleys are also made from wood, wrought iron and steel, in which case their structure is more complicated. In some engines the belt is attached directly to the flywheel, instead of to a separate pulley, thus making the flywheel do double duty.

The Oil Cup.

Whenever two pieces of metal are rubbed together continually it is necessary to introduce a thin film of oil between them in order to lessen the friction, and prevent heating. As this film must be constantly renewed, an oil reservoir or cup must be provided and attached in such a way that there is a duct leading from the cup to the surfaces in contact.

The perspective sketches (Exercises 31 and 32) show a brass cup, and the nipples and elbows which are necessary to attach it to the engine. Two forms of this cup are indicated, one having a hole in the bottom through which the oil is kept from flowing away too quickly by filling the cup with cotton waste, and the other having a brass tube screwed into this hole, into which the oil is slowly drawn by the capillarity of a piece of wicking.

Exercise 31.—Make a detail drawing of a brass oil cup according to the dimensions shown in the sketch. Scale, full size. Draw top view, half sectional front view, and bottom view of either form of oil cup.

The outside is to be finished all over. Seven required as follows: Two for the crosshead slides, one for the crosshead pin, one for the crank end of the connecting rod, two for the main bearings, and one for the eccentric. The edges of the cover are knurled, or roughened, so that it will be easier to unscrew.

Exercise 32.—Draw two views of each brass pipe fitting, shown in the sketches. Scale, full size.

(a) represents a 90° reducing elbow, into the larger end of which the oil cup is screwed, and into the smaller the nipple. Three required; two for the crosshead slides, and one for the crosshead pin.

(b) represents a 45° reducing elbow used for the same general purpose as (a). Four required; one for the crank end of the connecting rod, one for the eccentric, and two for the main bearings.

(c) represents a brass nipple, or short piece of brass pipe which connects the elbows with the specified engine part.

All threads are standard pipe threads, and are to be taken from Table II. The diameters given are nominal inside diameters, from which the corresponding actual diameters can be determined from the table.

PLATE X.

The Engine Frame.

The duty of the frame of an engine is to hold each part in its correct relation to all the others. Frames are usually made of cast iron, on account of their complicated form, although in special cases they are built up of wrought iron or steel.

The following points should be especially considered in designing an engine frame:

1. Its form must be such that it can be readily moulded and cast in the foundry.
2. Means must be provided at one end by which the cylinder can be firmly attached by bolts or studs. The combined area of the bolts at the bottom of the threads must be great enough to withstand the maximum pressure of the steam. See method of figuring diameter of piston rod and cap screws.
3. Some method must be devised for fastening the frame rigidly to a base, or to the foundation. This is usually done by providing holes through which project long foundation bolts, which are firmly imbedded in a concrete base.
4. There must be guides in which the crosshead can work back and forth.
5. Bearings must be provided for the shaft.
6. Openings should be left through which the crosshead and connecting rod can be oiled and adjusted.

Exercise 33.—Make a detail drawing of the cast iron frame for a 5″x6″ vertical engine. Scale, one-fourth size. Draw a plan, a front elevation showing a vertical section through one of the guides, a sectional side elevation, and a horizontal section through the guides showing the valve rod bracket.

The general form of the frame is that of the frustum of a cone having pieces sliced from two opposite sides. The curves in the top view formed by these flat surfaces should be worked out by the principles of projection, and not guessed at. For method, see Conic Sections on Second Year plates. The holes in the upper end of the frame should be of the proper diameter for 9/16″ stud bolts, and spaced to agree with the corresponding taps in the cylinder (Exercise 12). These studs are the same size as those for fastening the cover to the cylinder, so that a new drawing need not be made for them, but they should be specified in the Bill of Material. The tapped holes leading into the guides are for the oil cup shown in Exercise 31. The radius (C) of the guides must be the same as that of the crosshead slide shoes, Exercise 14, Plate V. The two bearings should be spaced to agree with the bearing surfaces of the shaft, Ex-

ercise 26. These bearings are lined with Babbitt's metal, an alloy which melts at a low temperature, and can be run in around the shaft after it is in place, thus forming a perfectly fitting, easily lubricated bearing. The bearings are stiffened on each side by ribs projecting out from the frame. For diameter of taps (D) see next paragraph under Caps. The bracket shown in the section is a guide for the end of the valve rod, to prevent it from buckling or bending. See that all inside corners are rounded with fillets, or small curves, which should be made with the compass.

Caps for Main Bearings.

The caps of the main bearings must be detachable, or it would be impossible to put the shaft in place.

When the piston starts on its upward stroke, the full force of the steam is acting to tear the cap from the bearing, and so the cap and the cap screws must be strong enough to withstand this stress. Suppose it has been decided that there are to be four screws, two in each bearing, then their combined area should be the same as the combined area of the bolts holding the cylinder on the frame; or if

A=area of one bolt at the bottom of the thread;
P=total pressure of the steam in the cylinder, =2500 pounds;
F=factor of safety, which is taken as 16 as the bearing is subjected to shocks;
St=tensile strength of steel, from Table I;
N=number of screws or studs.

$$\text{Then } A=\frac{P\times F}{St\times N} \qquad 20.$$

From this value of A the diameter (D) of the cap screws or studs, the diameter of the hole through the cap, and the diameter of the tap in the bearing can be determined by referring to Table III, where the nearest larger diameter corresponding to the area should be taken as D.

Making the joint between the cap and the bearing at an angle of 45° to the axis of the engine, in conjunction with the projections on the under side of the cap, relieves the stress on the cap and cap screws somewhat.

Exercise 34.—Make a detail drawing of the cast iron, Babbitt lined cap for the main bearing of a 5″x6″ vertical engine. Scale, one-fourth size. Draw plan and front elevation.

The total width of the cap (E) should be the same as the length of the bearing on the frame. The Babbitt metal extends into the cap in two places in order to keep it from turning with the shaft. The tapped hole in the top of the cap is for the oil cup, Exercise 31.

Exercise 35.—Make a detail drawing, two views, of the steel stud and nut to fasten the above cap to the bearing. Scale, one-fourth size.

Diameter as per formula above. The length is made up of the three parts, (F) which is equal to the thickness of the flange of the bearing, (G) which should be ⅛″ less than the thickness of the cap flange, and (H) which should be 3/16″ more than the thickness of the nut. See Table III for remaining dimensions.

Place drawings so that a space is left for the title in the lower right hand corner. See that all necessary notes, finish marks and dimensions are placed on drawings. Add these details to the Bill of Material, being careful that the proper number required of each is specified.

PLATE XI.

The Valve Gear.

Under this heading is included the valve proper, and also the rods and eccentric used to give this valve its corrcet position in relation to the ports for each possible position of the piston in the cylinder. Plate XI shows small scale drawings of the different parts suitable for working a piston, or cylindrical valve back and forth in a valve chamber, in the same way that the piston moves in the main cylinder. Plate XV shows these same parts assembled in their correct relation to each other.

Valves.

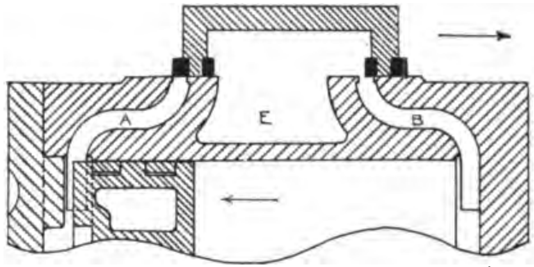
The simplest form of valve, the slide valve, is illustrated diagrammatically in Figure 12. It differs from the piston valve only in having its face flat, instead of round, the principle of the two being, however, exactly the same.

The valve must fulfill the following conditions:

1. It must admit steam only to the end of the cylinder from which the piston is moving, or is just getting ready to move.

2. It must allow the exhausted steam to pass out of the end of the cylinder toward which the piston is moving.

3. It must fit the valve seat accurately, or steam will enter the cylinder through the exhaust port, and acting against the moving piston reduce the mean effective pressure of the steam in the cylinder (M. E. P. of formula 15), and thus reduce the available horse power of the engine.



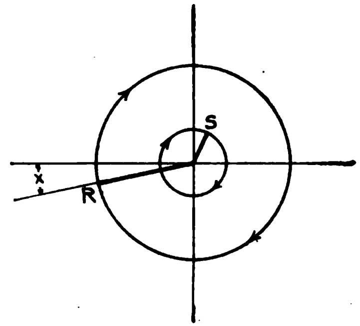


Fig. 12a

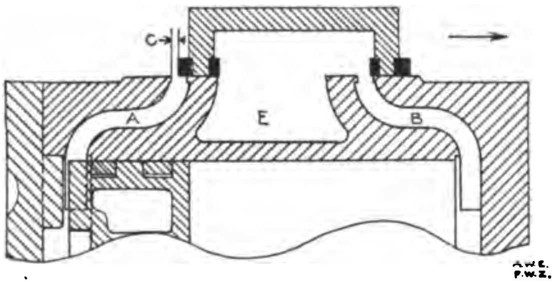
Point of Admission.

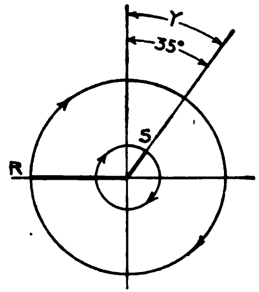
(a.)

The principal positions of the valve, together with the corresponding positions of the piston, crank and eccentric, are shown in Figure 12, the arrows denoting the direction of motion.

(a) shows the Point of Admission, or the place in the travel of the valve where it begins to open the port A to admit steam to the cylinder. Notice that the valve starts to open just before the piston reaches the end of its stroke, as otherwise the port would open so slowly that sufficient steam could not enter to completely fill the cylinder back of the piston. The angle (X) between this corresponding position of the

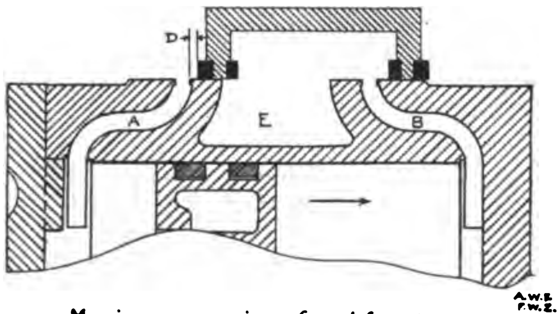
Fig. 12b

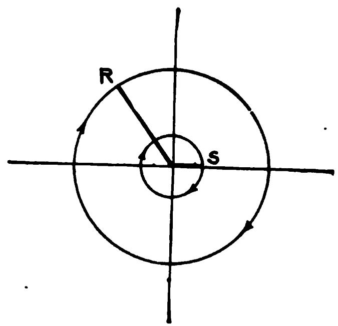




Piston at end of stroke.
Port partly open for admission.
(b)

Fig. 12c





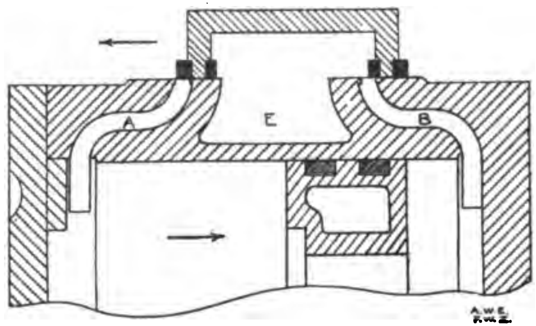
Maximum opening of port for steam.
(c)

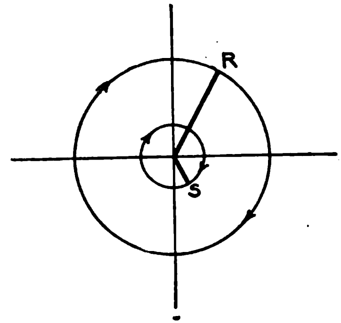
crank and the center line of the engine is known as the Lead Angle. (R) shows the position of the crank pin, and (S) that of the eccentric.

(b) shows the position of the valve when the piston is at the end of its stroke, or when the crank has swung through an amount equal to the lead angle. The amount of opening of the valve at this position (C) is known as the Lead. The amount that the eccentric is more than 90° ahead of the crank is known as the Angle of Advance, and is shown by the angle (Y).

(c) gives one limit of travel of the valve, and the maximum opening of the ports. The distance (D) is known as the Overtravel.

Fig. 12d

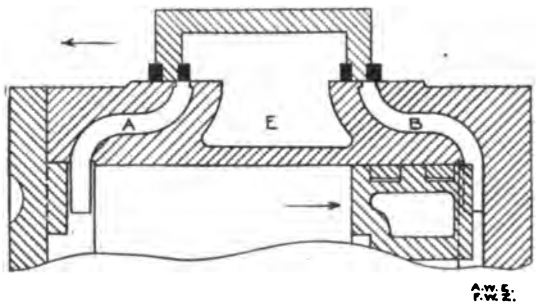


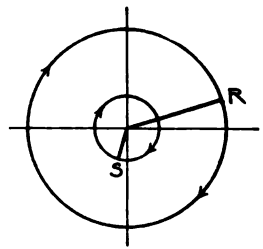


Point of cut off.
(d.)

(d) shows the Point of Cutoff, or position where the valve again covers the port, and thus prevents steam from entering the cylinder. Notice that the piston is still some distance from the end of its stroke. It is pushed the remainder of the way by the expansive force of the steam already in the cylinder.

Fig. 12e

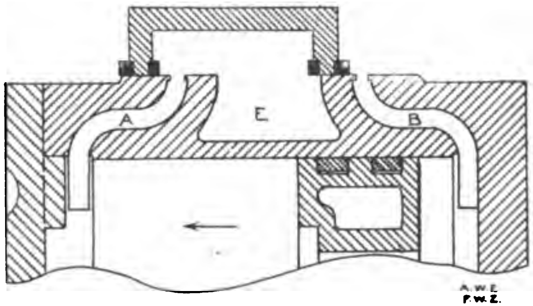


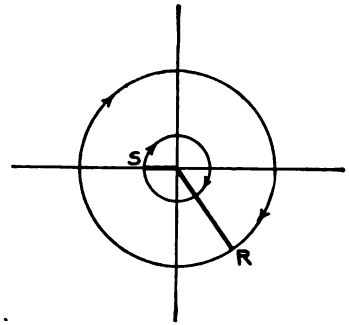


Point of exhaust.
(e.)

(e) illustrates the Point of Exhaust, the position where the port A is just being put in communication with the exhaust chamber (E).

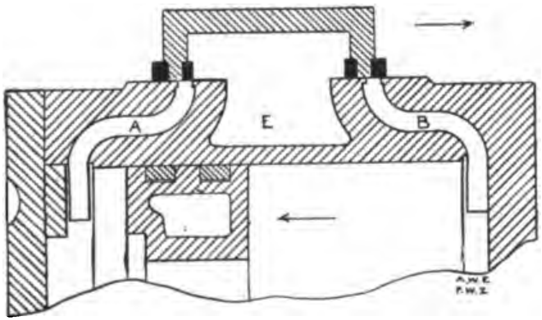
Fig. 12f

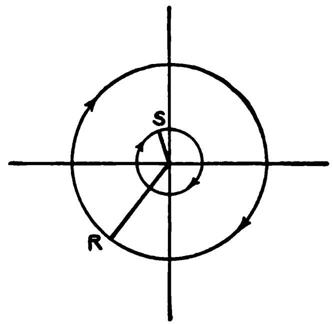




Maximum opening of port for exhaust.
(f)

Fig. 12g





Point of compression.
(g)

(f) gives the other limit of travel of the valve. The distance between the positions (c) and (f) is known as the Travel of the Valve, and is equal to twice the eccentricity, or throw of the eccentric, see Exercise 39.

(g) illustrates the Point of Compression, or position where the returning valve again covers the port A, and the piston begins to compress the exhaust steam left in the cylinder, thus forming a cushion to relieve the shock of suddenly changing the direction of motion of the piston, crosshead, etc.

To summarize, steam is admitted to the cylinder from the Point of Admission to the Point of Cutoff (a to d). The steam expands from the Point of Cutoff

to the Point of Exhaust (d to e). The used steam passes out through the port from the Point of Exhaust to the Point of Compression (e to g), and the remaining exhaust steam is compressed from the Point of Compression to the Point of Admission (g to a).

This same cylce of operations, of course, takes place at the other end of the cylinder, just one stroke of the piston behind that given above.

The amount that the outer part of the valve in its central position extends beyond the port is known as the Outside Lap (shaded black in the figures) and makes possible the period of expansion. The amount that the inner part of the valve extends over (also shaded black) is known as the Inside Lap and produces the period of compression.

The strength of the details shown on this plate can be made relatively much less than those heretofore drawn, as the work required of them is comparatively much lighter.

The determination of the proper proportions of the valve and valve gear is too complicated for discussion here, but can be found in J. S. and D. Reid's Machine Design, in Unwin's Machine Design, Vol. II, or in Kent's Mechanical Engineers' Pocket Book.

Exercise 36.—Make a detail drawing, two views, of a cast iron valve block for the 5″x6″ vertical engine. Scale, half size.

The shaded lines show the outside and inside laps. The diameter (D) must be the same as the diameter of the valve chamber, shown in the cylinder, Plate IV. The valve blocks are made to screw on to the valve rod, and then be locked in place by the nuts shown. Two required, one for each port.

Exercise 37.—Draw two views of the steel valve rod and locking nuts for the 5″x6″ vertical engine. Scale, half size.

The position of the valve blocks, and therefore of the nuts, is determined by the distance between the ports of the cylinder, see Plate IV. The rod between the two sets of nuts is turned down to a smaller diameter (E), which is the same as the diameter of the bolt at the bottom of the threads, see Table III. This decrease in diameter is often seen in long bolts, and makes what is known as a Bolt of Uniform Strength, as the strength of the threaded part is determined by its diameter at the bottom of the threads. The valve rod, and also the eccentric rod, Exercise 42, are shown with conventional breaks, as the total length is not drawn on account of lack of space. The lower end of the rod is threaded, so that it can be attached to the guide block. The nuts are standard.

Exercise 38.—Make a detail drawing, two views, of a steel guide block for the above valve rod. Scale, half size.

This block works back and forth in the bracket cast on the frame, in order to keep the valve rod from being bent by the sidewise thrust of the eccentric rod. The block should be tapped to fit the thread on the end of the valve rod. Make a note to this effect. The block is prevented from working loose by a ⅛″ steel pin, which is driven into a hole drilled through the block and rod end.

The Eccentric.

The eccentric is in effect a crank of small radius. It is used principally in places where the radius of the crank pin circle is less than the radius of the shaft, and where the eccentric transmits only a small part of

the power developed. This applies especially to valve gears, and therefore the eccentric is used almost universally to operate the valves of steam engines. Notice that while the crosshead, connecting rod and crank translate reciprocating into rotary motion, the eccentric and eccentric rod reverse this action, and change the rotary back into reciprocating motion.

The eccentric consists of two parts: First, the Sheave (Exercise 39), which is fastened to the shaft and revolves with it, and is so constructed that the center of the shaft is set eccentric with the center of the sheave; and, second, the Strap (Exercise 40) in which the sheave revolves, and which is made to work back and forth by the eccentricity of the sheave.

Exercise 39.—Draw two views of a cast iron eccentric sheave for the 5″x6″ vertical engine. Scale, ¾″=1″.

The eccentricity is ¾″, and as explained under valves, should be one-half of the required travel of the valve. The drill of the hole through the hub (G) should be the same as the diameter of the shaft. The arms projecting from the hub are to attach to the governor links, which keep the sheave in its proper relation to the shaft, according to the amount of work that the engine is performing.

Exercise 40.—Make a working drawing, two views, of the cast iron eccentric strap for the above sheave. Scale, ¾″=1″. Show the two pieces of the strap fastened together with the eccentric strap bolts.

The strap is made in two parts, so that it can be fitted over the rectangular projection on the face of the sheave, which prevents the strap from becoming displaced. The internal dimensions of the strap (H and J) are to agree with corresponding figures on the sheave. The tapped boss is to receive the end of the eccentric rod, the diameter of the tap (L) being the same as the diameter of the rod. The ⅛″ pipe tap is for the oil cup and connections, Exercises 31 and 32. The diameter (K) of the holes bored through the lugs for the bolts should be 1/16″ greater than the diameter of the bolts.

Exercise 41.—Make a detail drawing of the standord steel bolt for above eccentric strap. Scale, ¾″=1″. Diameter of bolt, 7/16″. Each bolt to have an extra standard steel lock nut.

Dimensions from Table III. Length of bolt to be determined from drawing of strap. Two required, finished all over.

Exercise 42.—Make a detail drawing, two views, of the forged steel eccentric rod for the 5″x6″ vertical engine. Scale, half size.

Show length less than scaled size with a conventional break. The boss at one end is to fit the valve rod block, Exercise 44. The number of threads per inch (M) must agree with the number marked on the boss of the eccentric strap.

Exercise 43.—Make a detail drawing of a special brass eccentric rod nut designed to lock the eccentric rod on to the strap. Scale, ¾″=1″.

This nut is to have the same form as the piston rod nut, Exercise 6, and all dimensions are to be in the same proportion to homologous dimensions in Exercise 6, as the eccentric rod diameter is to the piston rod diameter.

Exercise 44.—Draw three views of a steel valve rod block designed to connect the eccentric and valve rods. Scale, half size.

This block is designed to permit the setting of the eccentric rod at any desired position of the valve rod.

Exercise 45.—Draw two views of a standard steel set screw for above valve rod block. Scale, ¾″=1″. Diameter, length and threads are to be proportioned to fit tapped hole in block.

The standard proportions of set screws were discussed in connection with the connecting rod, Plate VI.

See that all necessary dimensions, notes and finish marks are included in the drawing, and then add these details to the Bill of Material.

The Governor.

A Governor is a piece of mechanism designed to make a steam engine run at a uniform rate of speed, however much the load on the engine may vary. In connection with Plate VIII it was explained how the flywheel, by storing up and giving out energy, equalized the speed through each revolution of the crank shaft. For longer periods of time than one revolution, however, the flywheel is useless, and it is for these longer periods that the governor is designed.

The action of most governors is based on the principle that the faster weights of any sort are made to revolve, the greater their centrifugal force, or tendency to fly out from the center will be. If then weights are made to revolve at the same relative speed as the engine, and the speed of the engine increases, the extra pull of these weights can be used to cut down the steam supply, or change the position of the valves in relation to the ports, thus reducing the speed of the engine. In this way the velocity of an engine may easily be made uniform within one or two per cent.

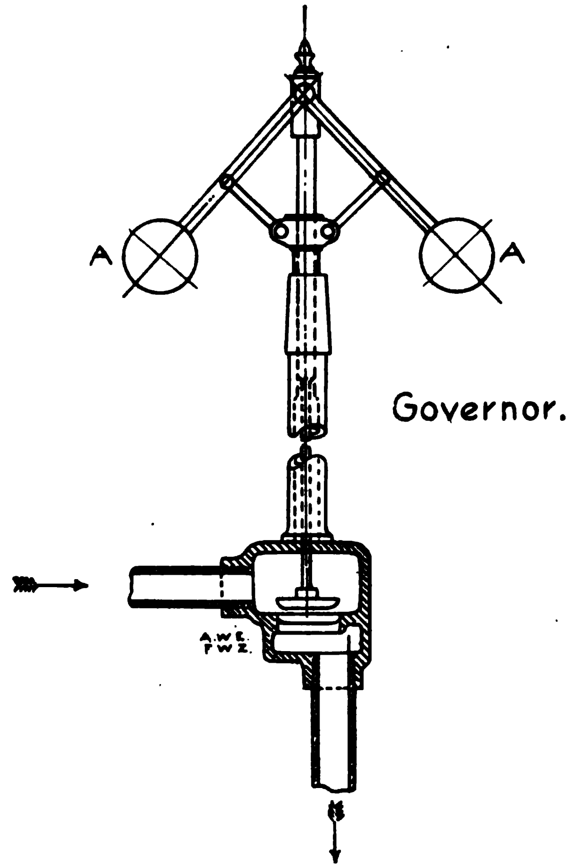


Fig. 13

Two general forms of engine governor are in use: First, the Throttle or Bly-ball governor shown diagramatically in Figure 13, in which the balls (A) act against the force of gravity and raise up as their speed

is increased, thus partially shutting off or throttling the steam supply of the engine; and, second, the Shaft or Flywheel governor shown on the assembled drawing, Plate XIII, in which the balls (A), acting against the springs (B), fly out from the center of the shaft as the speed is increased, thus shifting the eccentric and making the valve cut off the steam earlier in the stroke. It is easily seen that either method tends to reduce the speed as the balls fly out, and to increase it as they drop, and hence, within the certain narrow limits decided on by the designer, the shaft revolves with a uniform motion.

The governor shown on Plate XIII is made double to preserve the balance of the flywheel, as otherwise too much weight on one side at a high speed would cause the shaft to spring and run out of true. These parts are all shown in detail in the sketches on Plate XII, the numbers on the general drawing referring to the exercises on the detail sheet.

PLATE XII.

Details of Flywheel Governor.

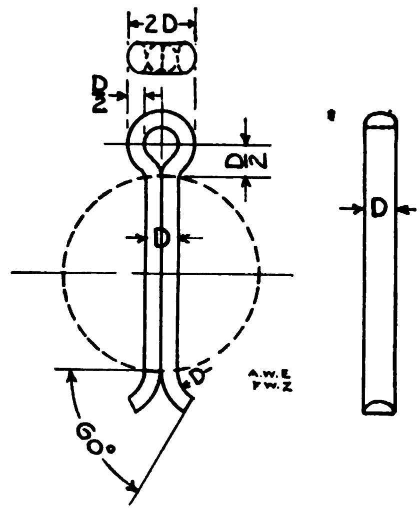
Exercise 46.—Make a detail drawing, two views, of the forged steel link for the flywheel governor of a 5″x6″ vertical engine. Scale, ¾″=1″.

The links connect the lever arms carrying the weights to the arms of the eccentric. Make all the small curves with the compass, and see that the thickness of the metal 5/16″ is preserved throughout.

Exercise 47.—Make a detail drawing, two views, of the six complete steel pins required in the construction of the above governor. Four wanted, 1¾″ long, of 47 a. Two wanted, 1⅞″ long, of 47 b. Scale, ¾″=1″.

These pins are alike except that two of them are ⅛″ longer than the others. In such cases it is usual to make only one drawing, on which the different sizes and number required of each are specified. These pins differ from a bolt in having a round head at one end, and at the other a washer which is kept in place by a ⅛″ split pin. This construction is allowable when there is little or no stress tending to pull the nut or washer from the bolt, as here, where all the force exerted tends to shear the pin. For proportions of split

Fig. 14



Split Pin.

pins see Figure 14. They are made by bending a piece of wire having a one-half round section into the form shown. The washer is to be ⅛″ thick, and its diameter is to be twice that of the steel pin.

Exercise 48.—Draw two views of the forged steel lever required in the construction of the above flywheel governor. Scale, half size.

By referring to the general drawing it will be seen that this lever is attached to a boss on the arm of the flywheel, and carries the weights or balls which shift the eccentric.

Exercise 49.—Draw all necessary views of the steel bolt, washer and nut used to attach the lever arm to the flywheel spoke. Scale, half size.

The threaded end of the bolt is turned down to a smaller diameter and the nut tightened against the shoulder thus formed, so that the lever arm will be left free to swing about the bolt as a pivot. The length of the bolt from head to shoulder (A) should be slightly greater, say 1/32″, than the thickness of the boss on the flywheel plus the length of the bore through the end of the lever arm. The washer is to be ⅛″ thick. For all other dimensions see Table III.

Exercise 50.—Make a detail drawing, two views, of the cast iron weights for above governor. Scale, half size.

Each weight is made in two parts so that it can be slipped in place over the lever arm. It is then fastened together with the steel studs, Exercise 51. Each ball complete is to weigh approximately eight pounds. Knowing the weight per cubic inch of cast iron, see Table I, figure the length (A) of the weight. Note that the weights are adjustable along the lever arm. The nearer the end of this arm they are, the greater their pulling power will be. This in connection with the adjustments of the spring, make it possible to set the governor, so that the engine will run constant at any desired speed.

Exercise 51.—Draw the necessary views of the steel stud and nut used to fasten the two parts of the weight together. Scale, half size.

The length of the thread (B) must be great enough to screw into the tapped half of the weight, plus 1/16″ for riveting. The thread (C) must be long enough for the standard nut. Dimensions of nut as usual.

Exercise 52.—Make a detail drawing, two views, of the coiled steel spring for above governor. Scale, half size.

The purpose of this spring, one end of which is attached to the lever arm, is to keep the weight from flying out and shifting the valve at a low speed. The stiffer the spring the higher the constant speed of the engine will be. Within certain limits the spring can be stiffened by tightening up the special bolt, Exercise 55. For method of drawing a spring see Exercise 5, Plate I. To save time, the helical curves may be drawn as straight lines, in the same way that screw threads are usually constructed. Either method may be used here at the discretion of the instructor.

Exercise 53.—Draw two views of the steel lever strap used to attach the spring to the lever arm. Scale, ¾″=1″.

The strap is to be sprung over the lever arm and then clamped in any desired position by the bolt, Exercise 54.

Exercise 54.—Draw the necessary views of the steel bolt, nut and split pin required for the above lever strap. Scale, ¾″=1″.

The diameter of the bolt is to be the same as the diameter of the hole through the lever strap. The split pin (see Exercise 47) is put through the bolt

just outside the nut, to keep the nut from working loose. The length of the bolt (A) must be equal to the distance through the lever strap, plus the thickness of the nut, plus the diameter of the split pin (⅛″), plus an amount of metal beyond the pin equal to twice the diameter of the split pin. All other dimensions and the threads are to be Standard.

Exercise 55.—Draw two views of the special steel spring bolt and nuts used for adjusting the spring of the above governor. Scale, ¾″=1″.

Two standard nuts are placed on each bolt, one each side of the strap, Exercise 56. The one next to the spring acts as a lock nut to prevent the other one from loosening, and changing the tension of the spring.

Exercise 56.—Make a detail drawing, two views, of the steel strap used for attaching the spring to the flywheel lug. Scale, ¾″=1″.

Draw all curves, however small, with the compass, using the same center for both outside and inside curves, so as to preserve thickness of metal throughout. The increased width at one end is necessary for the insertion of a wrench to tighten the nut of the spring bolt, Exercise 55.

Exercise 57.—Draw two views of the steel stops used to limit the swing of the weights of the above governor. Scale, full size.

Two of these stops are screwed into the arms of the flywheel in such a position that when the engine is at rest, the valve will be in the proper position to allow the steam to enter the cylinder. The other two are placed at the outer desired limit of swing of the weights.

Make the following into a title and place as usual in the lower right corner of the Plate: Details of flywheel governor, 5″x6″ vertical engine, scales 1″=1″, ¾″=1″, and ½″=1″, drawn by, checked by, approved by, date, school.

Have all dimensions, notes, sub-titles, finish marks, etc., carefully checked, and then add these parts to the Bill of Material. With this sheet the details of the engine are completed, the remaining plates being assembled or general drawings.

PLATE XIII.

General Arrangement of Governor.

In practice the assembled drawing would be made first, from a consideration of the work which it was intended that the governor should perform, and then the details would be worked out from this drawing, but here the student will build up the general drawing from the dimensions given in the preceding details.

Exercise 58.—Make an assembled drawing of the flywheel, governor and eccentric of a 5″x6″ vertical steam engine. Scale, 5/16″=1″.

Draw a front view, sectional bottom view, and sectional side view, leaving out bottom rim of wheel in side view to make room for title.

Draw the flywheel first in all three views, using the dimensions given on Plate VIII, and then place the stops (Exercise 57) in position in the holes tapped in the arms. Next draw the lever arms (Exercise 48) so that they rest against the inner stops. Draw each part in all three views as you proceed. Then place the weights midway between the shoulder and the end of the lever arm, and place all parts of the spring in

position, so that the lever strap (Exercise 53) comes against the shoulder. Draw the curves of the spring as straight lines. To locate the link and eccentric strike an arc from the center of the flywheel having a radius equal to the length of the eccentric arm (3¼″), and then intersect this arc with another having its center at the center of the boss on the end of the lever arm, and its radius equal to the length of the link. The intersection of these arcs locates the center of the pin, Exercise 47a. No dimensions, notes or finish marks required. Shade all curved surfaces with line shading, so as to show the form of each detail. See notes and examples of line shading on page 47, Book I.

PLATES XIV, XV AND XVI.

Assembled Drawings of 5″x6″ Vertical Steam Engine.

The arrangement of these drawings is shown on the plates. All dimensions are to be taken from the preceding detail sheets. If made to the scale of ¼″= 1″, these drawings will go singly on a standard sheet, but if larger boards and paper are available, it is recommended that the scale be half size, and if possible that all three views be made on one paper. It would be better also to set the engine in a different part of the stroke from that shown; for instance, it can be set with the piston at the upper or lower limit of stroke, at three-fourths stroke, and so on, each different position, of course, changing the position of all the moving parts of the engine. The top view can be varied by taking half sections at different altitudes of the frame or cylinder. The vertical sections can also be made half section and half outside view, if it is so desired.

Exercise 59.—Draw a vertical section of the 5″x6″ steam engine, taken on a plane which cuts through the center line of the engine at right angles to the crank shaft. Scale as above.

Draw the frame first, then the cylinder in its correct position on the frame, showing the cylinder head, stuffing box and all studs in their right places. Put the piston in the position desired by the instructor, and then draw the other parts in their order as given in the exercises. A point on the center line of the engine, 18″ up from the center of the crank shaft will be the center of travel of the crosshead pin. The distance of the pin from this point will be equal to the distance of the center of the piston from the center of the cylinder. To find the position of the crank pin, draw the crank pin circle, and intersect it with an arc struck from the center of the crosshead pin, and having a radius equal to the length of the connecting rod. Note the position of the crank pin corresponding to the position of the piston at the middle of its stroke. Make the angle of advance of the eccentric equal to 35° (see valves). Draw the visible parts of the governor, flywheel and valve gear, but do not try to put in too much detail or too many hidden lines. Draw the base and foundation bolts as shown.

Exercise 60.—Draw a vertical section of the 5″x6″ steam engine taken on the center line at right angles to the section of Exercise 59. Scale as above.

This exercise is in reality a side view of Exercise 59, and, as such, all dimensions possible should be taken from that drawing. The correct position of the valve in relation to the piston should be determined on a separate piece of paper, or on the drawing of Exercise 59, by laying out to scale a diagram similar to

those of Figure 12, working from the given position of the eccentric and ports, and from the known radius of the eccentric circle (¾"), and the travel of the valve (1½"). The different parts of the valve gear are numbered to agree with the Exercises of Plate XI.

Exercise 61.—Draw a half sectional plan of the 5"x6" vertical engine, the section to be taken at the place indicated by the instructor. Scale as above.

Dimensions are to be taken from Exercises 59 and 60. Do not attempt to show too much hidden detail, as it tends to confuse the drawing. Line shading may be used to bring out the form of the various parts.

No dimensions or notes are to be placed on these three exercises. Titles are to be designed in which each pupil determines his own wording and general arrangement, and which in style are in accord with those of the previous drawings.

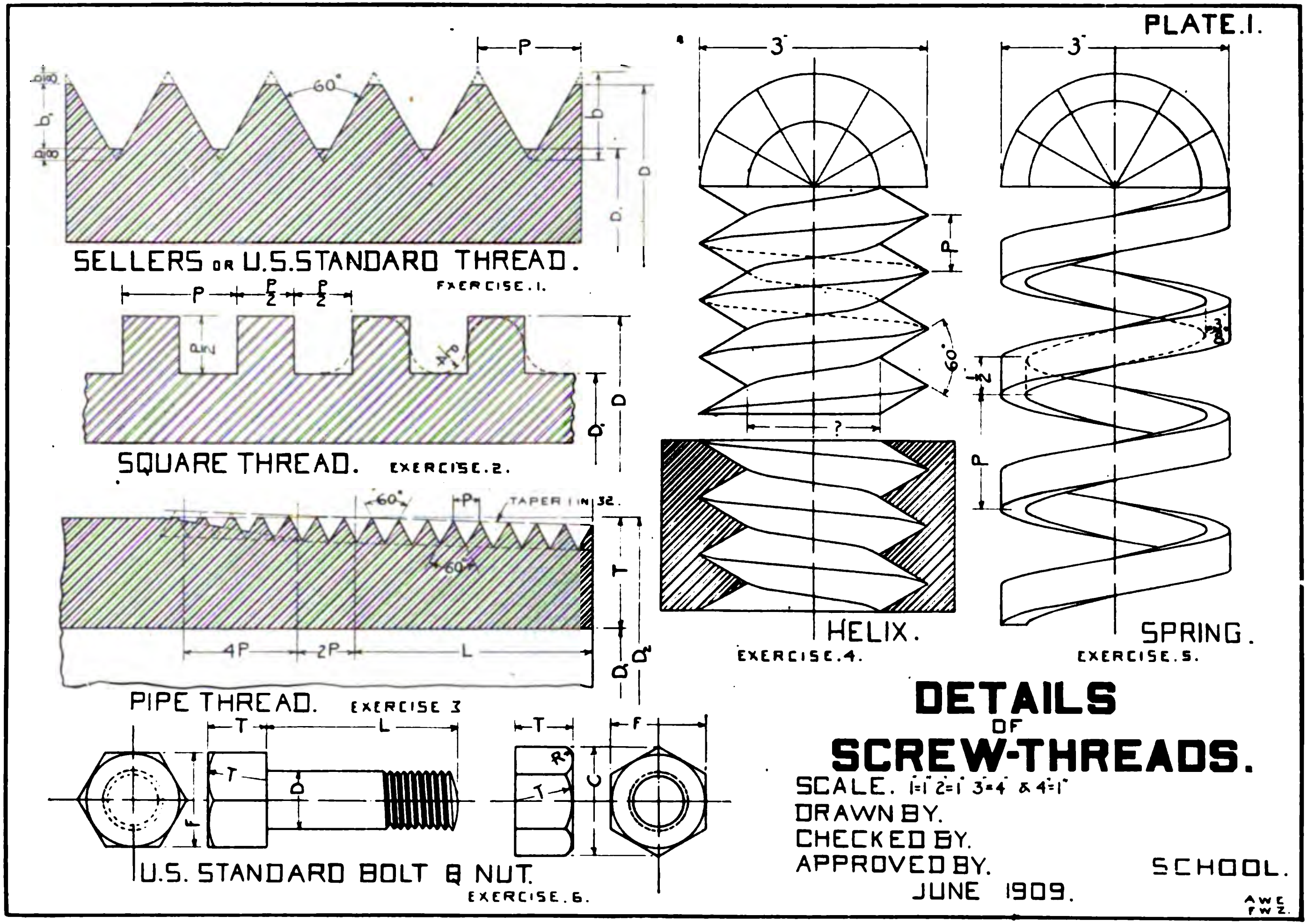


PLATE. I.
SELLERS OR U.S. STANDARD THREAD.
EXERCISE. 1.
SQUARE THREAD. EXERCISE. 2.
TAPER 1 IN 32.
PIPE THREAD. EXERCISE 3
HELIX.
EXERCISE. 4.
SPRING.
EXERCISE. 5.
U.S. STANDARD BOLT & NUT.
EXERCISE. 6.
DETAILS
OF
SCREW-THREADS.
SCALE. 1=1" 2=1" 3=4" & 4=1"
DRAWN BY.
CHECKED BY.
APPROVED BY.
JUNE 1909.
SCHOOL.
A W E
F W Z.

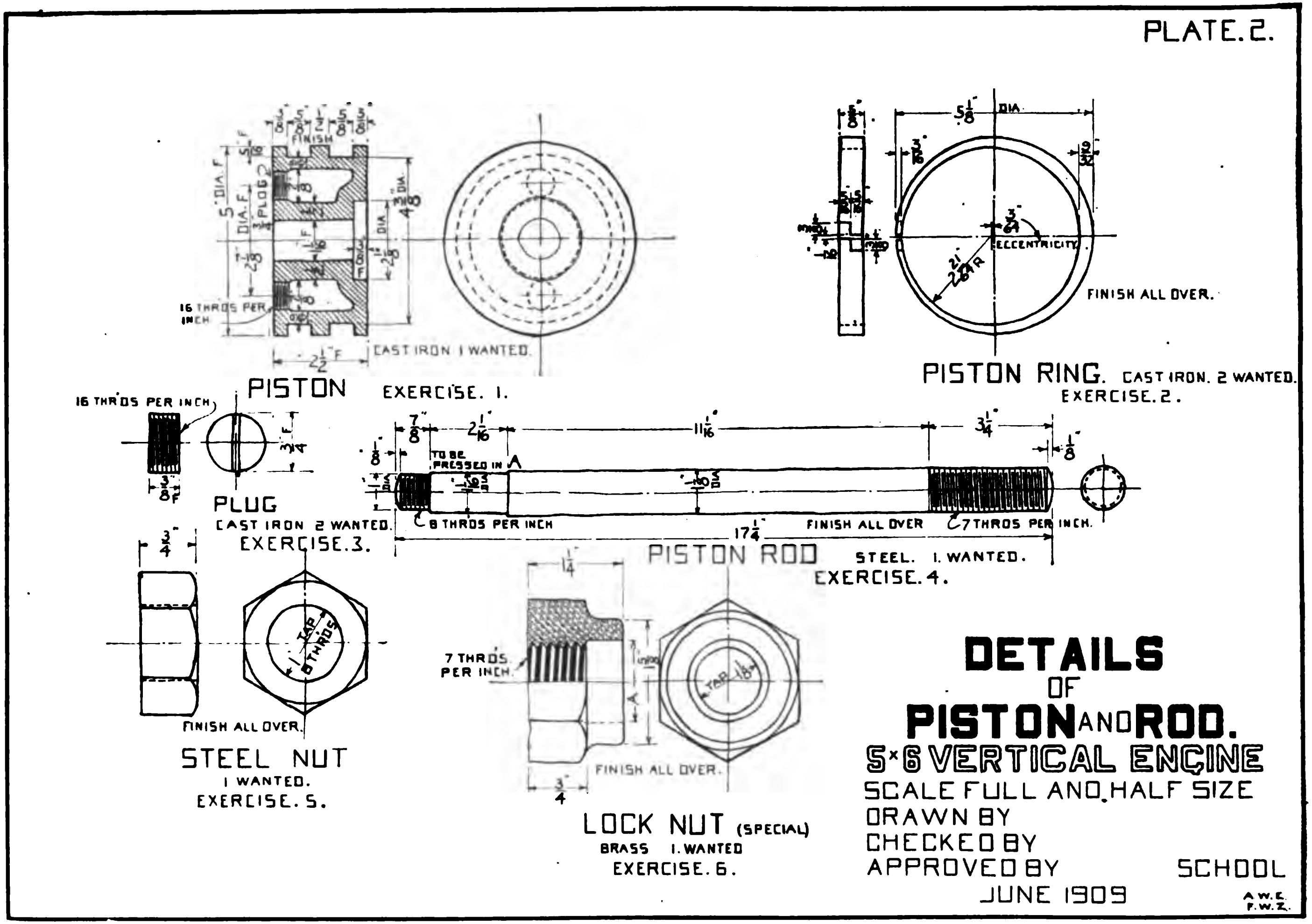


PLATE. 2.
PISTON EXERCISE. 1.
CAST IRON 1 WANTED.
16 THRDS PER INCH
PISTON RING. CAST IRON. 2 WANTED.
EXERCISE. 2.
FINISH ALL OVER.
ECCENTRICITY
DIA.
PLUG
CAST IRON 2 WANTED.
EXERCISE. 3.
TO BE PRESSED IN
8 THRDS PER INCH
FINISH ALL OVER
7 THRDS PER INCH.
PISTON ROD STEEL. 1. WANTED.
EXERCISE. 4.
FINISH ALL OVER.
STEEL NUT
1 WANTED.
EXERCISE. 5.
7 THRDS. PER INCH.
FINISH ALL OVER.
LOCK NUT (SPECIAL)
BRASS 1. WANTED
EXERCISE. 6.
DETAILS OF PISTON AND ROD.
5×6 VERTICAL ENGINE
SCALE FULL AND HALF SIZE
DRAWN BY
CHECKED BY
APPROVED BY
SCHOOL
JUNE 1909
A.W.E. F.W.Z.

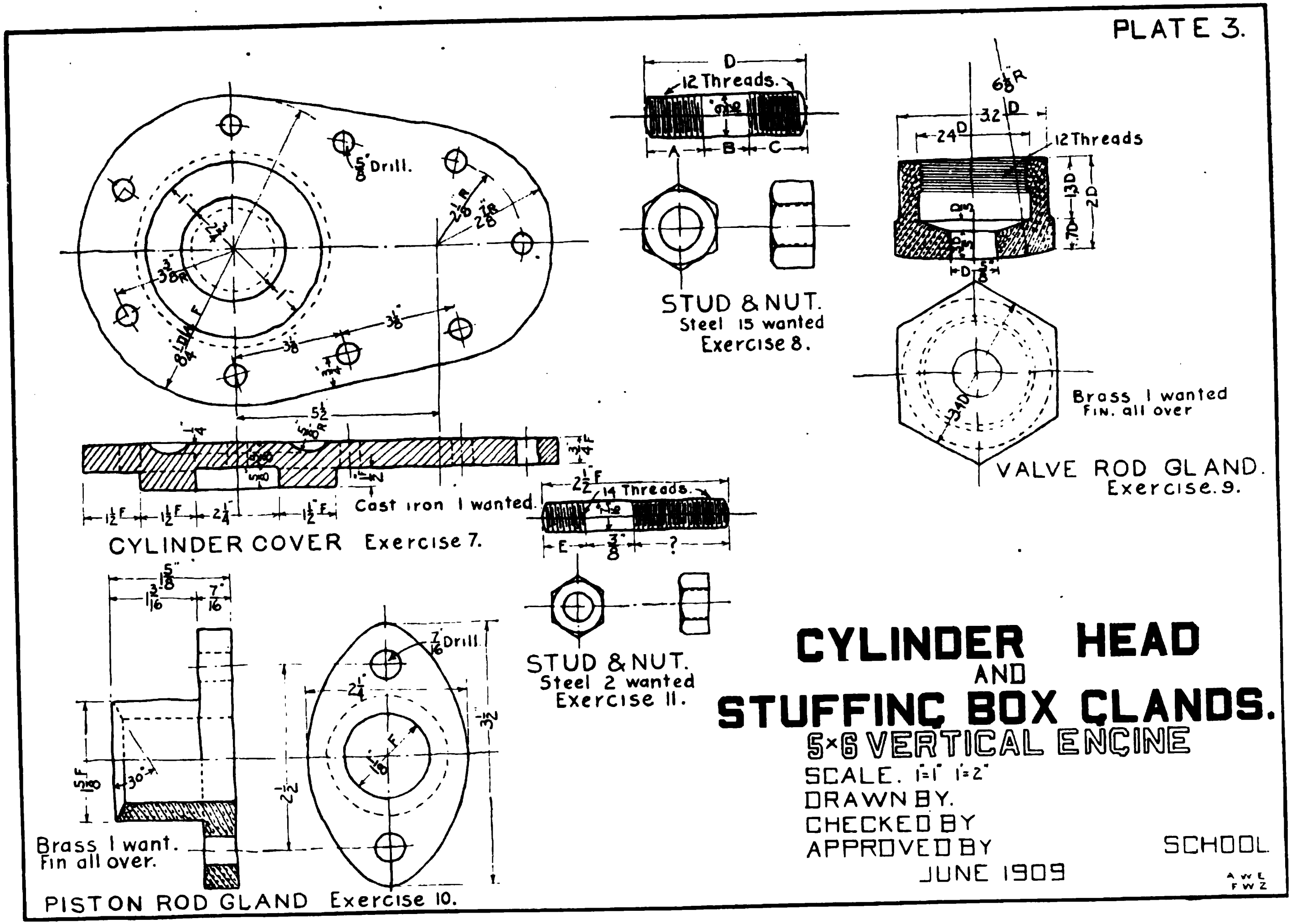


PLATE 3.
5/8" Drill.
CYLINDER COVER Exercise 7.
Cast iron 1 wanted.
12 Threads.
STUD & NUT.
Steel 15 wanted
Exercise 8.
12 Threads
Brass 1 wanted
Fin. all over
VALVE ROD GLAND.
Exercise. 9.
14 Threads.
STUD & NUT.
Steel 2 wanted
Exercise 11.
7/16 Drill.
Brass 1 want.
Fin all over.
PISTON ROD GLAND Exercise 10.
CYLINDER HEAD
AND
STUFFING BOX GLANDS.
5×6 VERTICAL ENGINE
SCALE. 1=1" 1=2"
DRAWN BY.
CHECKED BY
APPROVED BY
JUNE 1909
SCHOOL

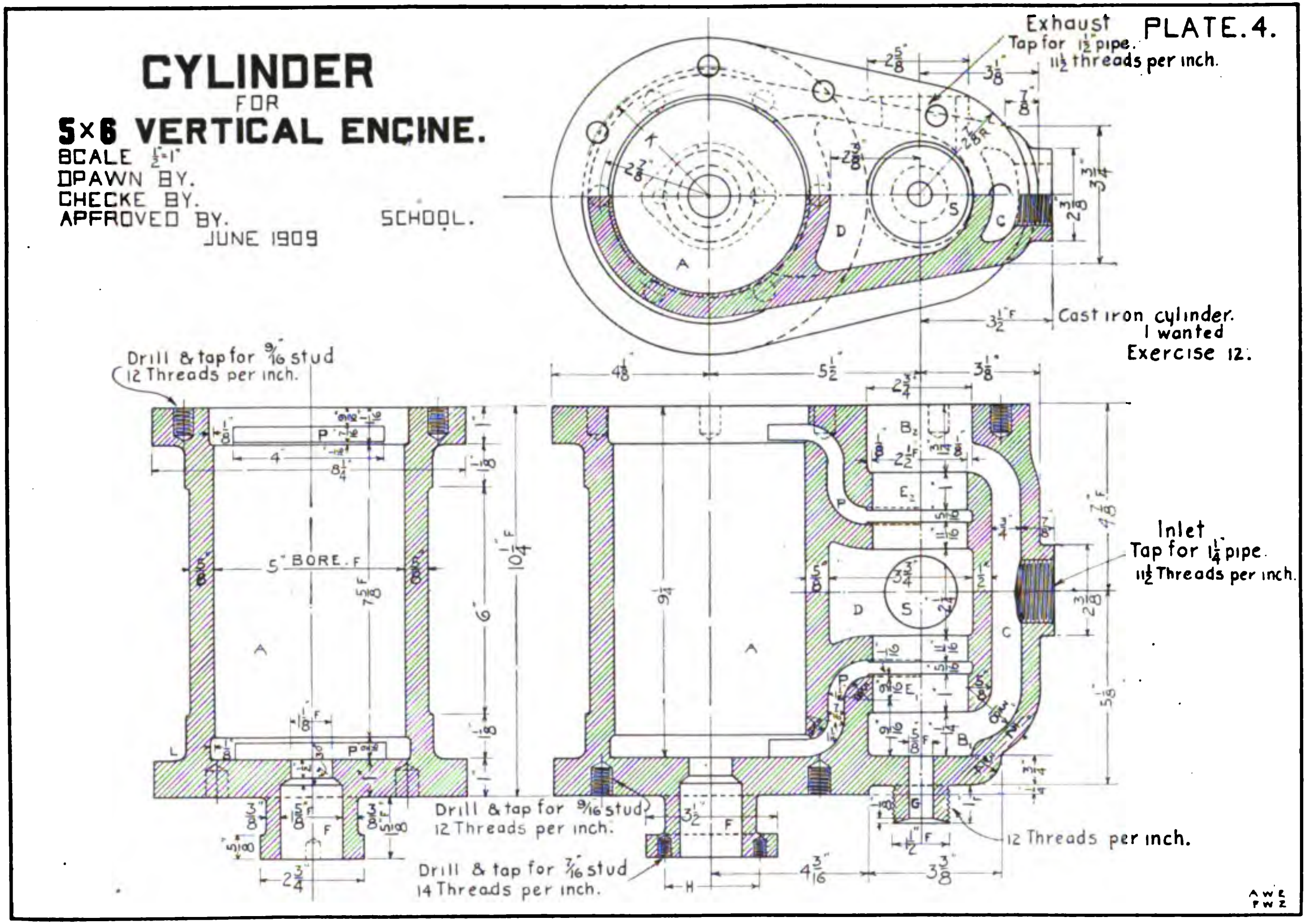


PLATE. 4.
CYLINDER
FOR
5×6 VERTICAL ENGINE.
SCALE ½=1"
DRAWN BY.
CHECKE BY.
APPROVED BY.
SCHOOL.
JUNE 1909
Exhaust
Tap for 1½" pipe.
11½ threads per inch.
Cast iron cylinder.
1 wanted
Exercise 12.
Drill & tap for 9/16 stud
12 Threads per inch.
5" BORE. F
Inlet
Tap for 1¼" pipe.
11½ Threads per inch.
Drill & tap for 9/16 stud
12 Threads per inch.
Drill & tap for 7/16 stud
14 Threads per inch.
12 Threads per inch.
A. W. E.
F. W. Z.

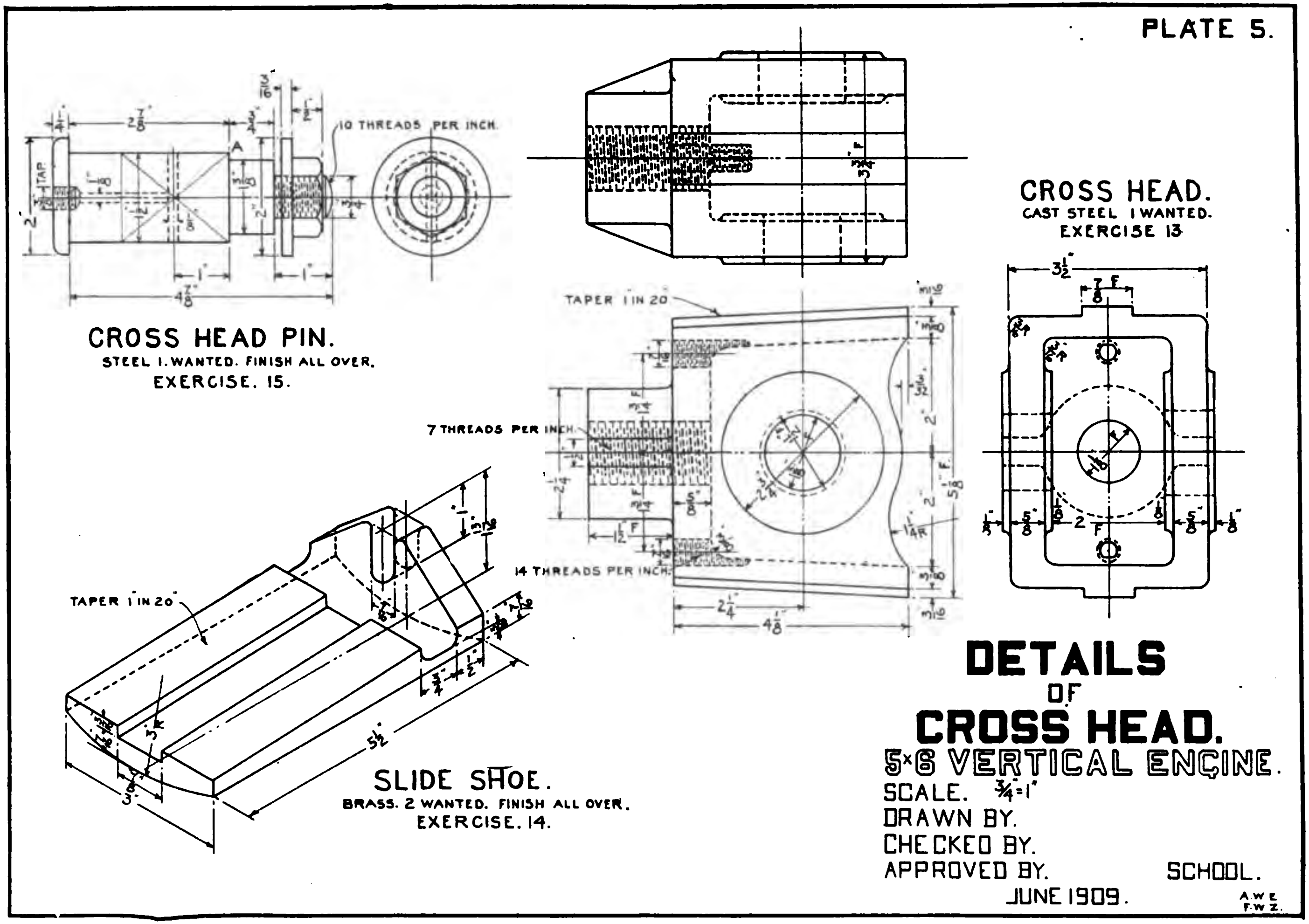


PLATE 5.
CROSS HEAD PIN.
STEEL 1. WANTED. FINISH ALL OVER.
EXERCISE. 15.
10 THREADS PER INCH.
CROSS HEAD.
CAST STEEL 1 WANTED.
EXERCISE 13
TAPER 1 IN 20
7 THREADS PER INCH.
14 THREADS PER INCH.
TAPER 1 IN 20
SLIDE SHOE.
BRASS. 2 WANTED. FINISH ALL OVER.
EXERCISE. 14.
DETAILS
OF
CROSS HEAD.
5×6 VERTICAL ENGINE.
SCALE. ¾=1"
DRAWN BY.
CHECKED BY.
APPROVED BY.
SCHOOL.
JUNE 1909.
A.W.E.
F.W.Z.

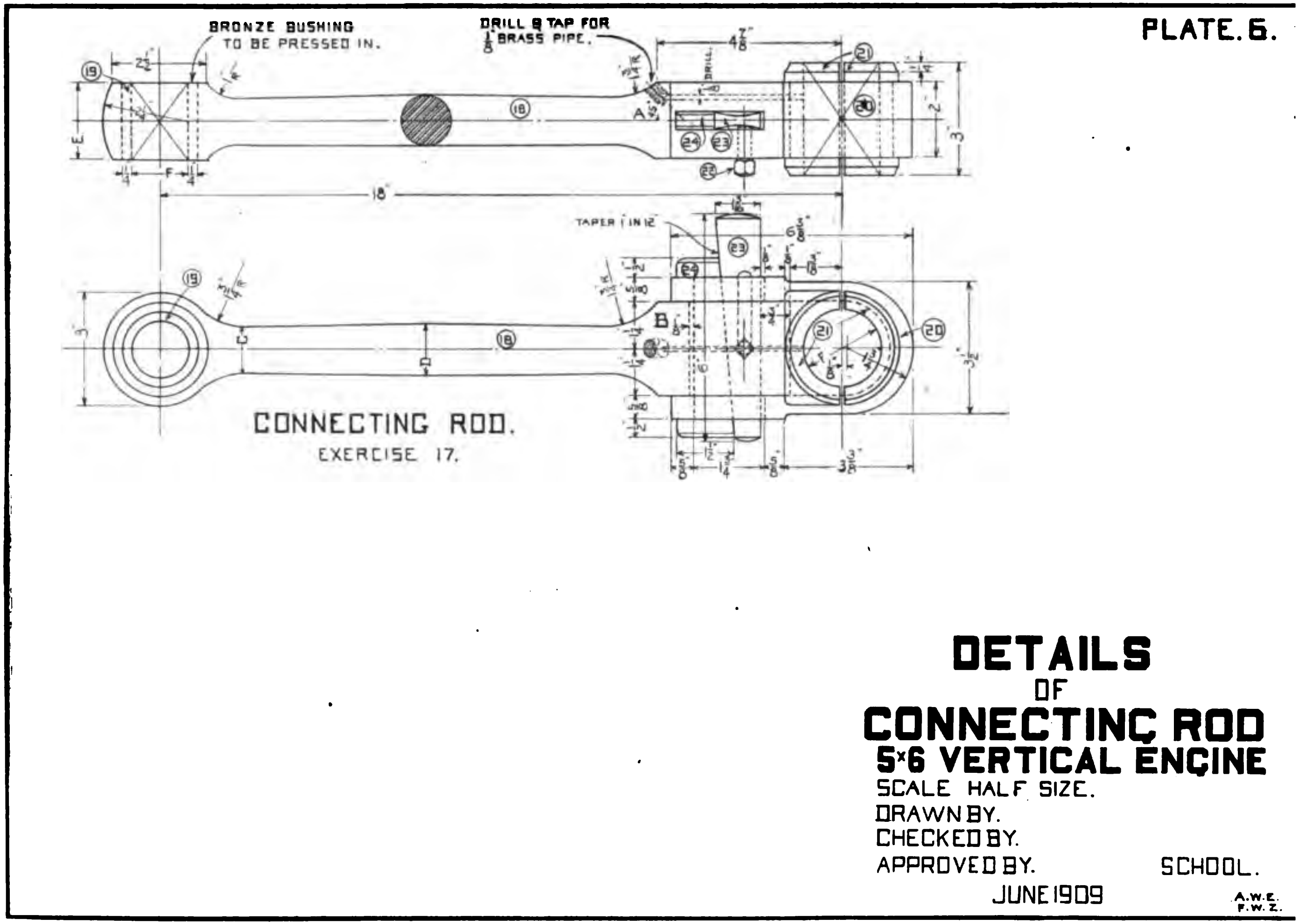


PLATE. 6.
BRONZE BUSHING TO BE PRESSED IN.
DRILL & TAP FOR 1/8" BRASS PIPE.
TAPER 1 IN 12
CONNECTING ROD.
EXERCISE 17.
DETAILS
OF
CONNECTING ROD
5×6 VERTICAL ENGINE
SCALE HALF SIZE.
DRAWN BY.
CHECKED BY.
APPROVED BY.
SCHOOL.
JUNE 1909
A.W.E.
F.W.Z.

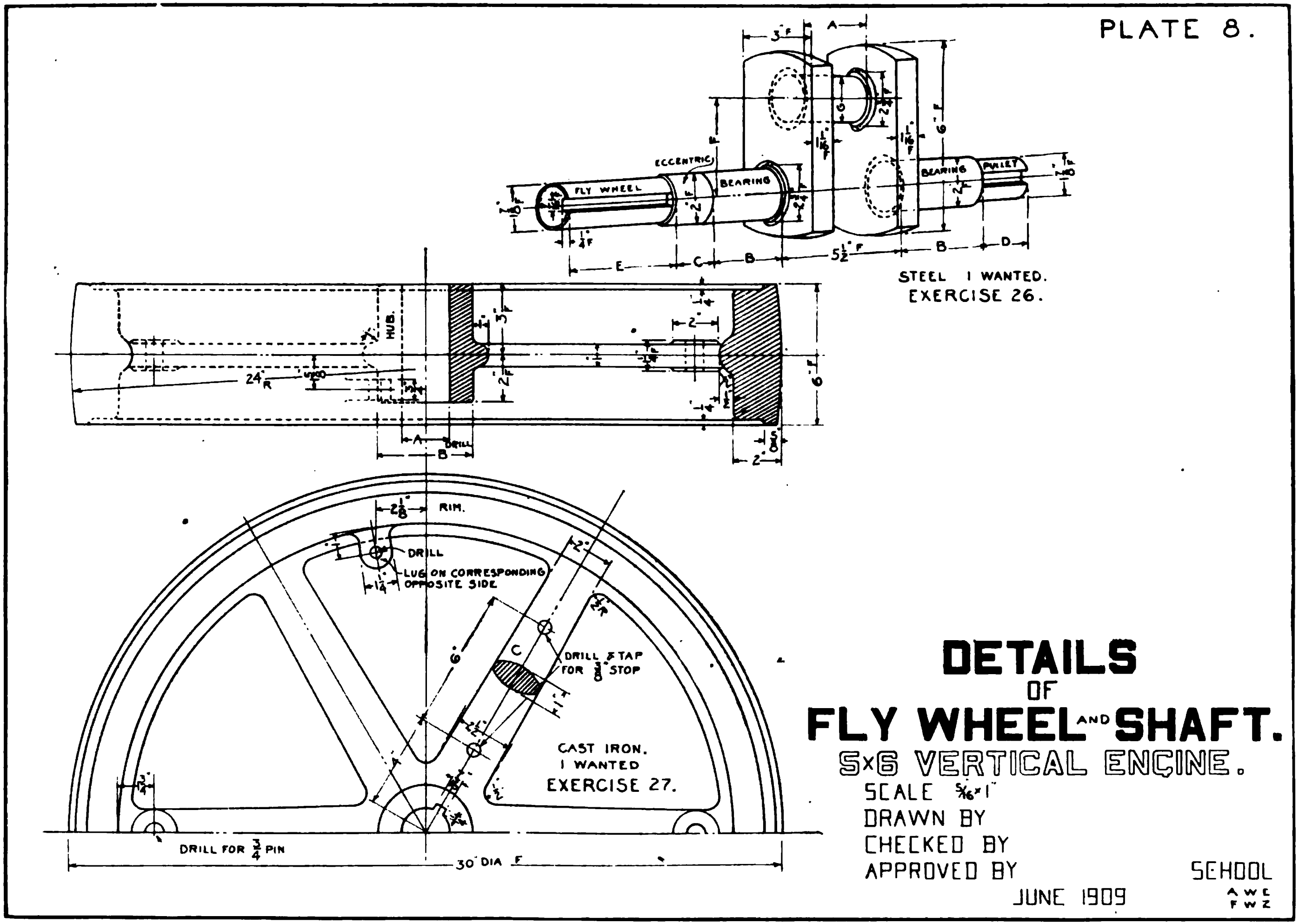


PLATE 8.
ECCENTRIC
FLY WHEEL
BEARING
PULLEY
STEEL 1 WANTED.
EXERCISE 26.
HUB.
RIM.
DRILL
LUG ON CORRESPONDING OPPOSITE SIDE
DRILL & TAP FOR 3/8" STOP
CAST IRON.
1 WANTED
EXERCISE 27.
DRILL FOR 3/4 PIN
30" DIA F
DETAILS
OF
FLY WHEEL AND SHAFT.
5×6 VERTICAL ENGINE.
SCALE 3/16×1"
DRAWN BY
CHECKED BY
APPROVED BY
SCHOOL
JUNE 1909

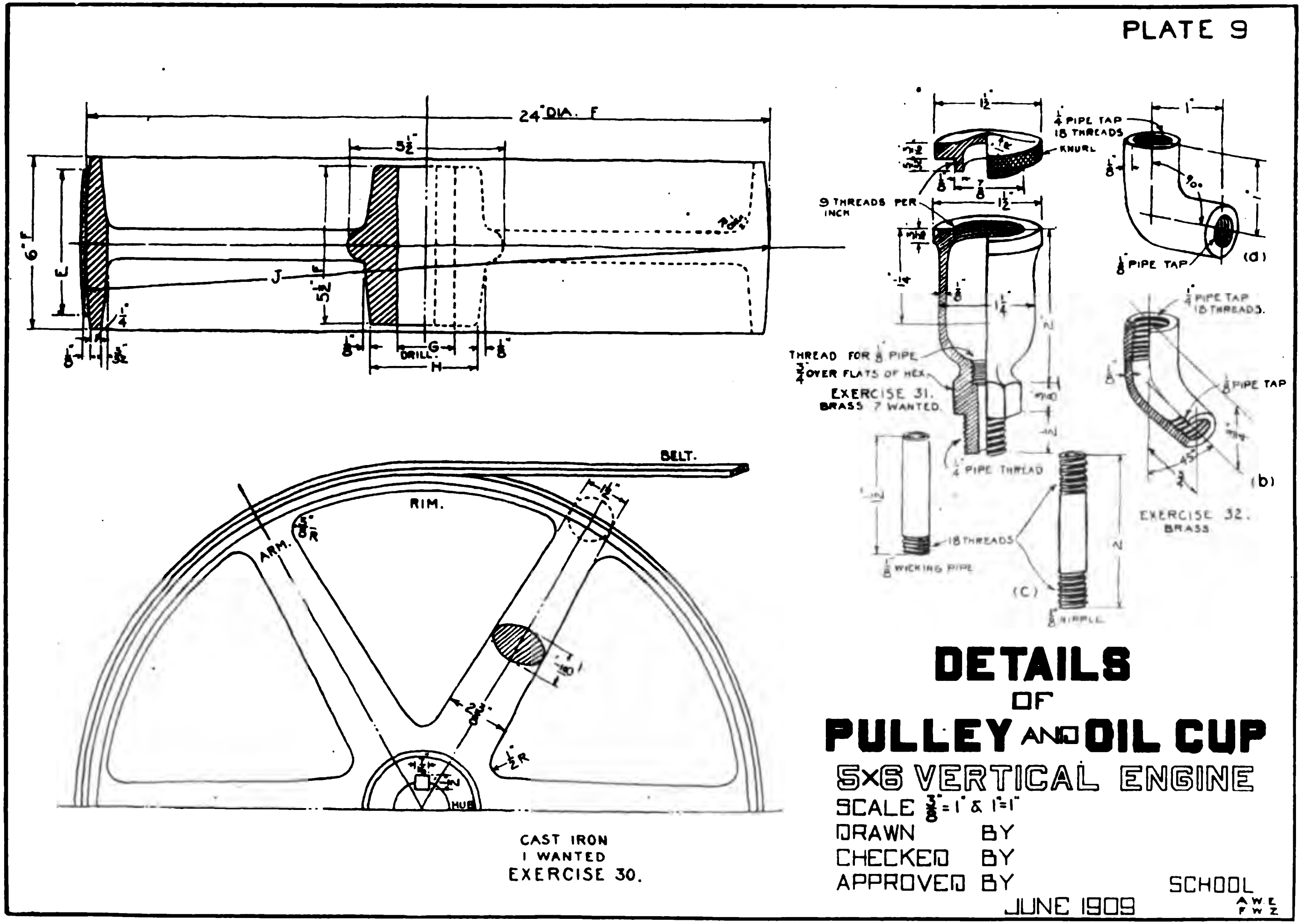


PLATE 9
24" DIA. F
6" F
E
J
$5\frac{1}{2}$"
$5\frac{1}{2}$" F
DRILL
G
H
BELT.
RIM.
ARM.
HUB
CAST IRON
1 WANTED
EXERCISE 30.
$\frac{1}{4}$" PIPE TAP
18 THREADS
KNURL
9 THREADS PER INCH
THREAD FOR $\frac{1}{8}$" PIPE
$\frac{3}{4}$" OVER FLATS OF HEX.
EXERCISE 31.
BRASS 7 WANTED.
$\frac{1}{4}$" PIPE THREAD
18 THREADS
$\frac{1}{8}$" WICKING PIPE
$\frac{1}{8}$" NIPPLE
(c)
$\frac{1}{8}$" PIPE TAP
(d)
$\frac{1}{4}$" PIPE TAP
18 THREADS.
$\frac{1}{8}$" PIPE TAP
45°
(b)
EXERCISE 32.
BRASS
DETAILS
OF
PULLEY AND OIL CUP
5×6 VERTICAL ENGINE
SCALE $\frac{3}{8}$"=1" & 1"=1"
DRAWN BY
CHECKED BY
APPROVED BY
SCHOOL
JUNE 1909
A W E
F W Z

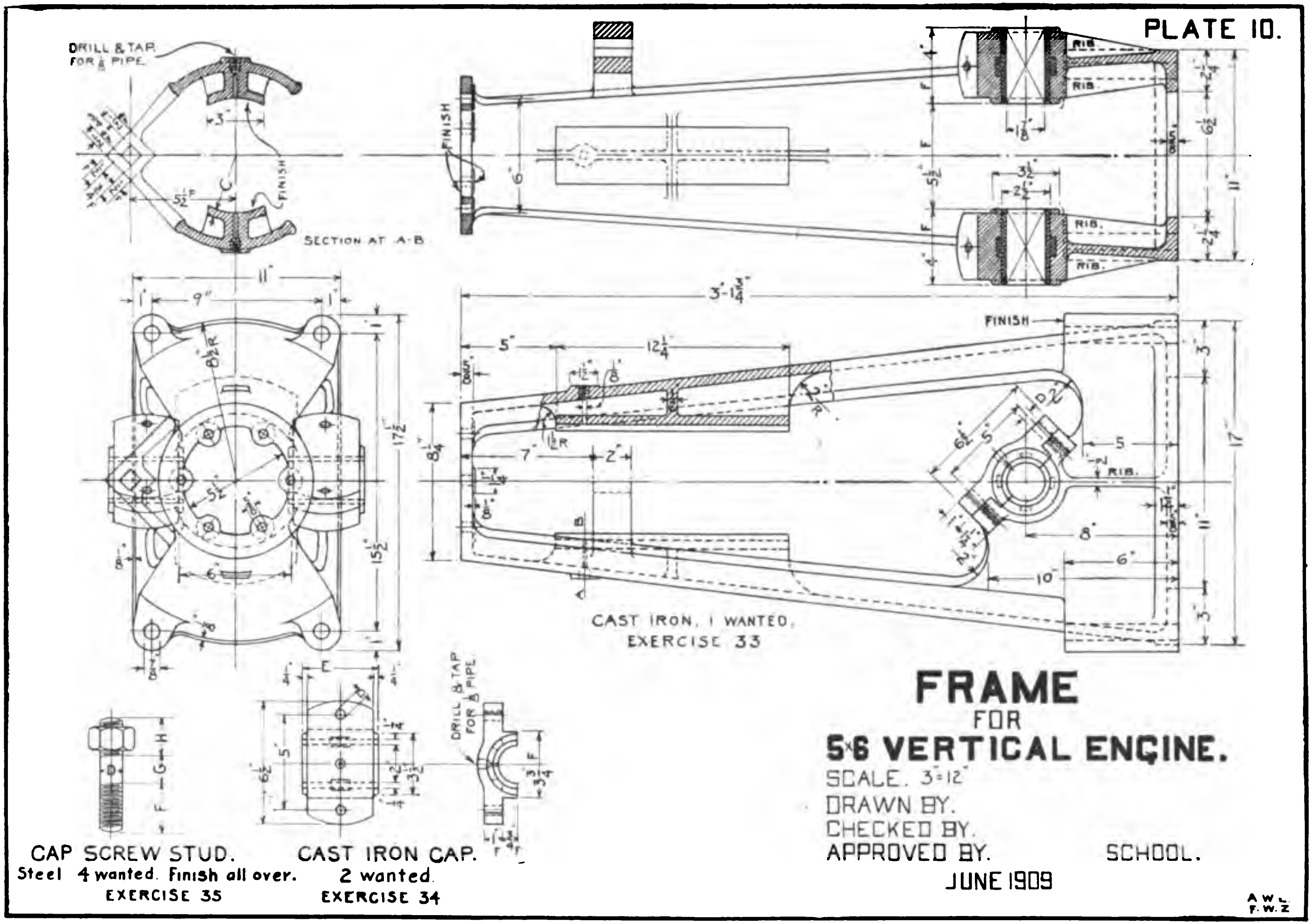


PLATE 10.
DRILL & TAP FOR 1/8 PIPE
FINISH
SECTION AT A-B
RIB.
FINISH
CAST IRON, 1 WANTED.
EXERCISE 33
DRILL & TAP FOR 1/8 PIPE.
FRAME
FOR
5x6 VERTICAL ENGINE.
SCALE. 3"=12"
DRAWN BY.
CHECKED BY.
APPROVED BY.
SCHOOL.
JUNE 1909
CAP SCREW STUD.
Steel 4 wanted. Finish all over.
EXERCISE 35
CAST IRON CAP.
2 wanted.
EXERCISE 34
A.W.L.
F.W.Z.

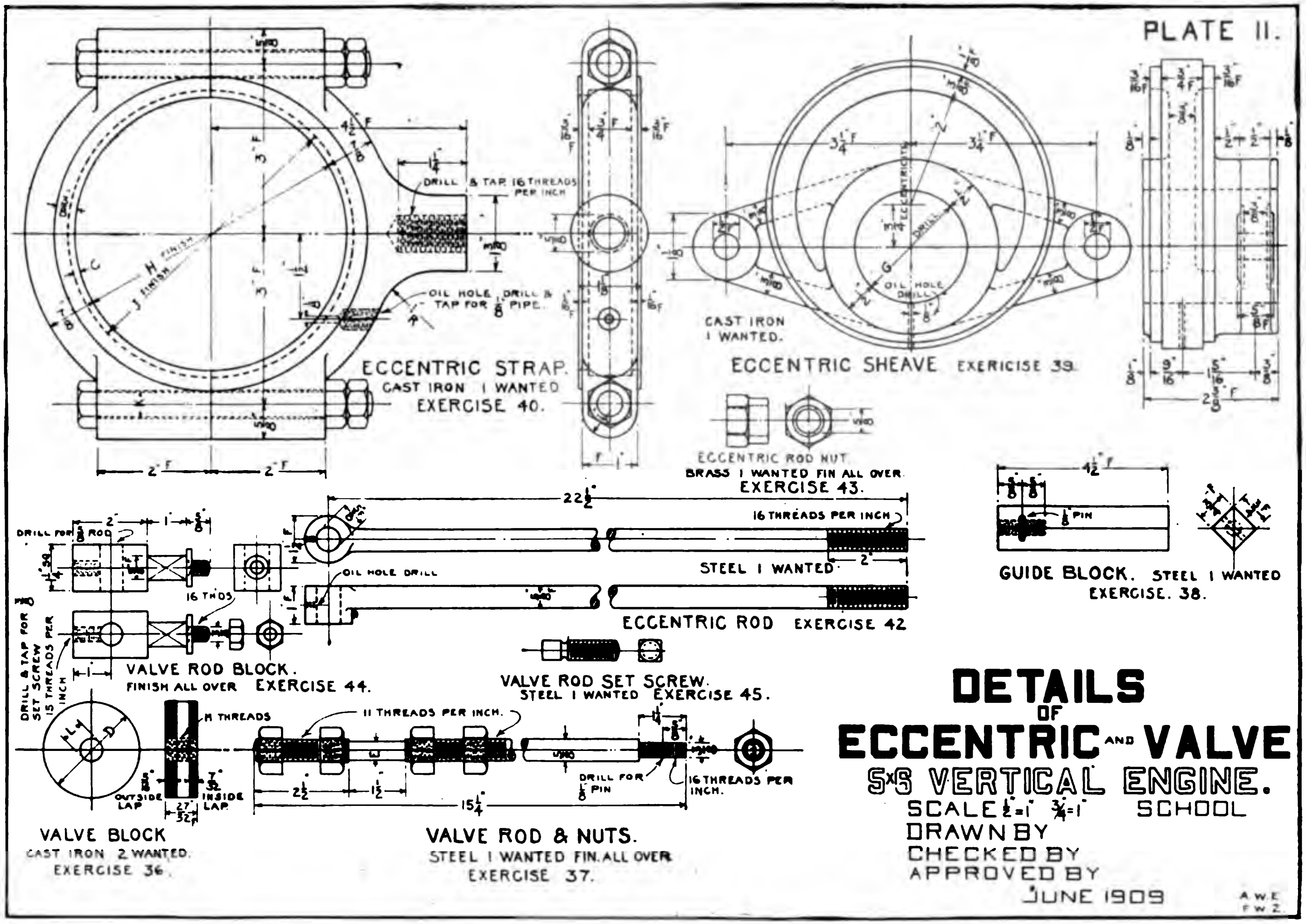


PLATE II.
ECCENTRIC STRAP.
CAST IRON 1 WANTED
EXERCISE 40.
ECCENTRIC SHEAVE EXERCISE 39.
CAST IRON
1 WANTED.
ECCENTRIC ROD NUT
BRASS 1 WANTED FIN ALL OVER.
EXERCISE 43.
GUIDE BLOCK. STEEL 1 WANTED
EXERCISE. 38.
STEEL 1 WANTED
ECCENTRIC ROD EXERCISE 42
VALVE ROD BLOCK.
FINISH ALL OVER EXERCISE 44.
VALVE ROD SET SCREW.
STEEL 1 WANTED EXERCISE 45.
VALVE BLOCK
CAST IRON 2 WANTED.
EXERCISE 36.
VALVE ROD & NUTS.
STEEL 1 WANTED FIN. ALL OVER
EXERCISE 37.
DETAILS
OF
ECCENTRIC AND VALVE
5x6 VERTICAL ENGINE.
SCALE 1/2=1" 3/4=1" SCHOOL
DRAWN BY
CHECKED BY
APPROVED BY
JUNE 1909
A.W.E.
F.W.Z.

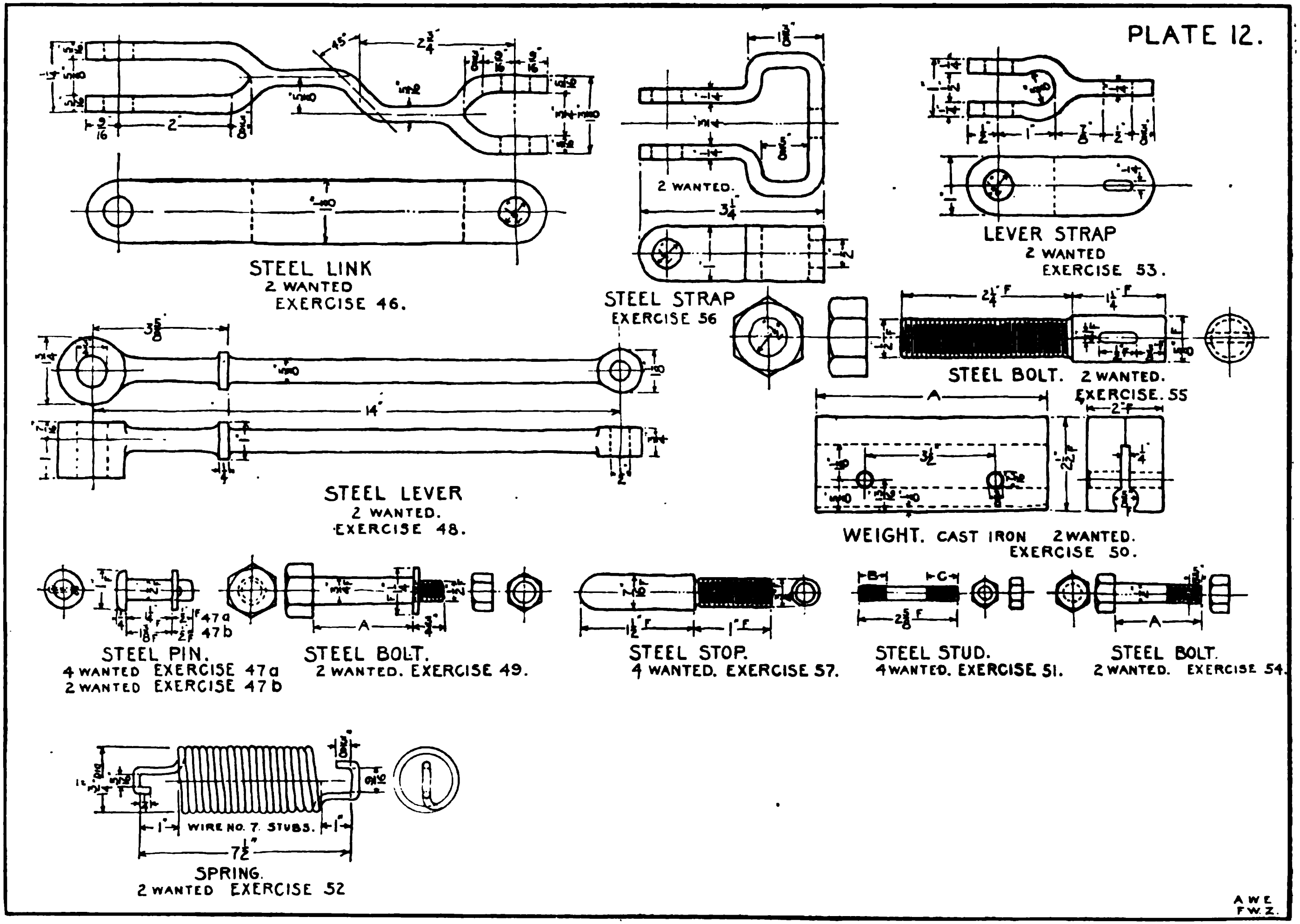
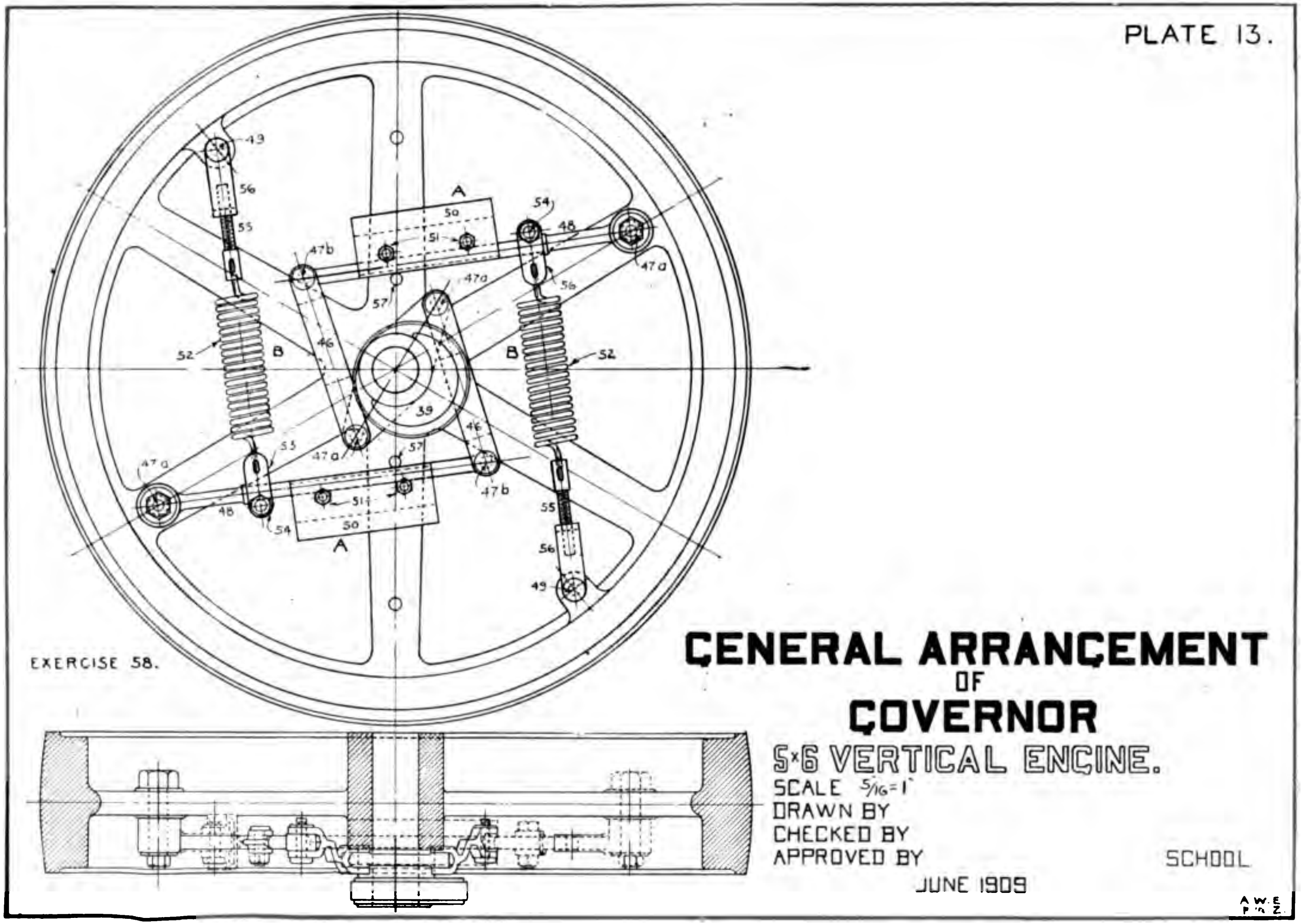


PLATE 12.
STEEL LINK
2 WANTED
EXERCISE 46.
2 WANTED.
STEEL STRAP
EXERCISE 56
LEVER STRAP
2 WANTED
EXERCISE 53.
STEEL BOLT. 2 WANTED.
EXERCISE. 55
STEEL LEVER
2 WANTED.
EXERCISE 48.
WEIGHT. CAST IRON 2 WANTED.
EXERCISE 50.
STEEL PIN.
4 WANTED EXERCISE 47a
2 WANTED EXERCISE 47b
STEEL BOLT.
2 WANTED. EXERCISE 49.
STEEL STOP.
4 WANTED. EXERCISE 57.
STEEL STUD.
4 WANTED. EXERCISE 51.
STEEL BOLT.
2 WANTED. EXERCISE 54.
WIRE NO. 7. STUBS.
SPRING.
2 WANTED EXERCISE 52
A.W.E.
F.W.Z.

For plates 14-15 see pocket at end of b.



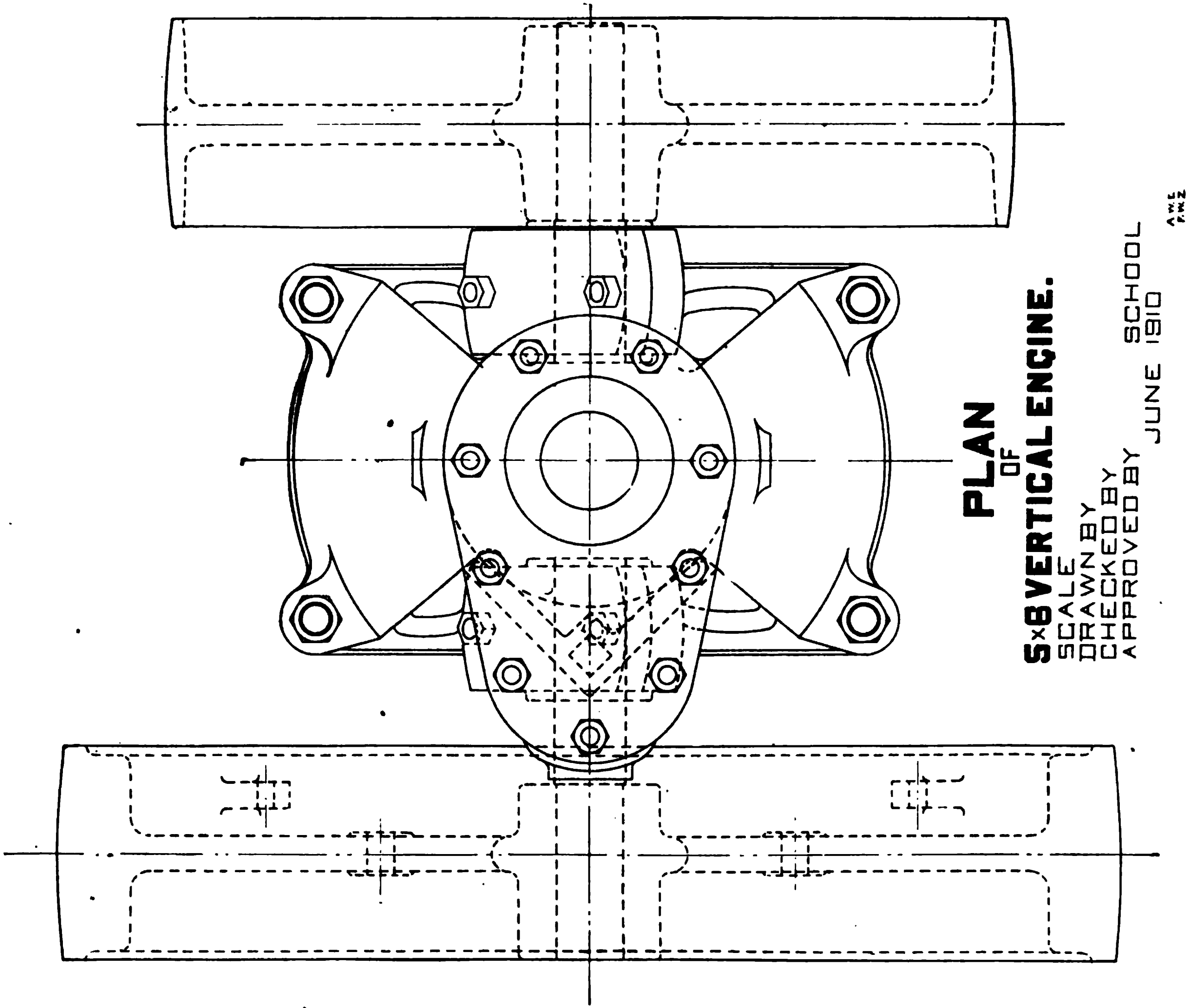

PLAN OF 5×8 VERTICAL ENGINE.
SCALE
DRAWN BY
CHECKED BY
APPROVED BY
SCHOOL
JUNE 1910

PLATE XVI

COURSE C.

Architectural Drawing and Construction.

By Percy H. Sloan.

Note.—The various methods of construction described herein are based on Chicago practice simply because the author's experience and observation are almost wholly limited thereto. However, "Chicago methods" are very generally followed throughout the country, especially where similar building conditions prevail.

Being merely an interested layman and teacher, not an architect, the author takes pleasure in acknowledging the aid of Harry A. Merrick and Edgar S. Belden, Architects, especially of the former, who reviewed his work and contributed many helpful suggestions thereto.

But most of all, he is indebted to his mother, whose patience and devotion have permitted him the time in which to bring his labors on this and on the other parts of the book to completion.

Introductory.

From remote antiquity, house building has been among civilized man's most necessary occupations. Today those employed in the structural trades and professions constitute a very large part of the world's workers, and some familiarity with architectural practice in drafting, and some knowledge of the rudiments of building construction, are now essential to almost all men, irrespective of their vocations. To supply the student with such information is the purpose of these plates and the accompanying text. However, the student's time will not permit his undertaking other than a simple example of a very common type of structure, and these pages and plates must not be considered by him as other than constituting a most elementary course in the subject.

And, both that he may read the text with fuller understanding, and that he may execute his drawings with greater intelligence, the student is urged to supplement his school room work by observation afield. Opportunity for this he will never lack, so general is the building activity in our city at all times.

Let us assume that we are to build for a client an eight room brick residence, which is to have modern conveniences, is to be adapted in style and size to a suburban lot of fifty feet frontage, is to face west and to cost about $5,000.00.

The requisites for the work are: First, a set of drawings, comprising plans, elevations, details of construction and of finish, these to show arrangement, dimensions, appearance, etc., of the proposed building in general and in detail. Second, a set of specifications to supplement the drawings, wherein are stated the kind and quality of the materials to be used, the methods of work to be employed, the class of workmanship required, the fittings to be supplied, and other things not possible to show in the drawings.

Third, a contract or contracts, setting forth, among other things, the time of completion of the several parts, and of the whole job, and the terms of payment therefor. Lastly, when all is in readiness for the construction to begin, the drawings must be approved by the proper authorities, and permits for the work obtained from them.

The Design.—First let us sketch, regardless of actual sizes, an experimental arrangement of rooms, giving them convenient and suitable locations according

to their respective uses, and also giving some thought as to how we may finish them. As most plans are based on the rectangular parallelogram, its subdivisions and modifications, let us start with a square cut by diameters into quarters, which we will call rooms.

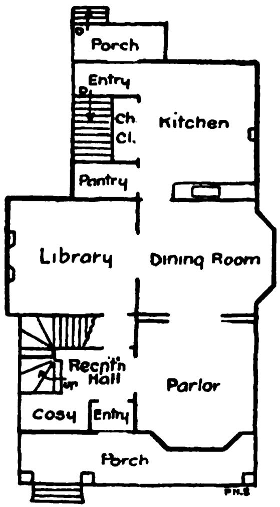


FIG 1

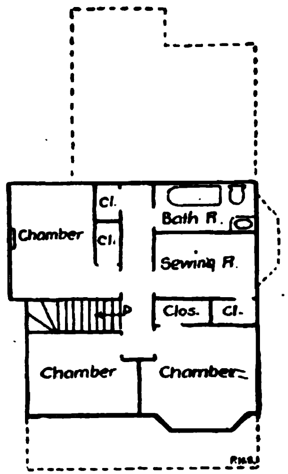


FIG. 2

As it is of greater interest, we will begin with the first floor plan. Now, in general, all other exposures are preferable to a north one for the main living rooms. Then, allotting the northwest subdivision to the entrance hall and the stairs to the second floor, suppose we assume the southwest room to be the parlor. We will extend the front of this in a bay for the sake of additional space, and of the variety thus secured both within and without. We will light the room through windows in the bay only, for many housekeepers object to a strong, direct sunlight in their parlors; and in fact, a somewhat subdued light seems more in accord with the character of such a room. Also, by so doing, we can reserve the south wall as a fine unbroken space for later decorative treatment.

Adjoining the parlor on the east, but possible of being cut off therefrom by sliding doors, we will place the dining room, to which let us also add a bay, this on the south, so that here we may get all the sunlight and cheer possible. By covering the walls with golden buff burlap and tinting the ceiling to match, we will make this a delightfully bright room. In agreeable contrast we will have the trim (woodwork) of antique oak.

The remaining division of our square, opening from the dining room, let us call the library. This room being perfectly square, its proportions seem monotonous, so let us set the north wall out a distance, to our taste. In this wall we will put an ample fireplace for comfort, and for aesthetic and sentimental reasons as well. And to cut off the outer world, and to secure an appropriately quiet atmosphere, we will place the windows high; in fact, we will have their benches (inner window sills) on a level with the mantel. For convenience let this room also open into the reception hall.

We must now make provision for a kitchen. In line with the parlor and dining room, as an addition to our square, with an east and south exposure, we will plan a generous, well lighted and well appointed kitchen, reserving its north wall for basement stairs, china closet, and pantry. In the last of these, sunlight certainly is not wanted. This addition need be but one story high.

In our first, the northwest division, by placing the stairs about the angle furthest from the front door (which latter we wish somewhat centrally located), we can make them an attractive feature, can secure space beneath them for a wardrobe, and also reserve a cozy corner in the reception hall. We will light the hall by a fixed window of ornamental glass placed high, and the stairs in a similar way. Thus we have on the first floor, four of the eight rooms required; space has been used economically and partitions are in nice alignment. See Fig. 1.

As the kitchen addition is but one story high, our second floor plan complete is practically a square. On this floor four rooms are required besides the bath. By locating one in each of the three corners other than the southeast, and by placing the bath and a small sewing room here, we can meet the requirements. See Fig. 2.

Experiment shows that by running a hall east and west through the center from the head of the stairs, we can get all these rooms to the outside, which is desirable, as chambers should always be well lighted and airy. The alignment of partitions should correspond to those of the floor below as much as possible, although this, of course, can seldom be throughout.

Closets we must plan so as not to spoil or needlessly use room space. The bath room should have a south exposure and be placed so that its service pipes may be carried directly from the basement with those of the kitchen. We will carry up the parlor bay, but not that of the dining room.

In the basement there should be a laundry convenient to the kitchen and to the yard; also a heater room, coal bins, shop and storage spaces.

As our residence is to have suburban environments, a commodious front porch is almost a necessity.

In carrying forward the scaled drawings we probably will find occasion to deviate from these sketches and notes, but they at least will give us something to start with. In fact, the pupil is encouraged to consider and to carry out, under the guidance of the teacher, changes in these plans, etc., that may occur to him.

Now let us begin our actual drawings. At the outset it is necessary to state that in these we must make everything calling for such consideration ample in size for safety, must comply with all building requirements imposed by law, should follow the accepted best practice in construction, avoid unusual sizes in the selection of materials, and try to make our design simple and well balanced, and our drawings complete.

We will not here attempt explanations of the methods of calculating correct sizes of supporting members, posts, girders, joists, etc., or of foundations and walls. It is now sufficient to say that such are determined from estimates of the work demanded of them, that is, the loads they are to carry and how they carry them, all of which comprise a part of the mathematics of architecture, a knowledge of which is essential to the architect. Later, as we undertake some work in original design, we will give attention briefly to the subject of "Strength of Materials"—Chapter III.

For our drawings we will use Whatman's cold pressed paper, size 15″x22″, although commonly the architect uses a much inferior paper.

The scale that is noted on each illustration is that to which the student is to make his drawing. In most cases these are the scales usually employed for such work. The student is expected to place his work

well, to be accurate, and to give his plates in every way a draftsmanlike finish, with clean cut lines, carefully executed printing and figures, etc.

Readily to distinguish from one another the various materials used in construction, it is the general practice to give fixed colorings to the sectional views of the parts; thus wood sections, such as frame partitions, timbers, etc., are tinted yellow; brick work in section, as of chimneys and walls, red; and sections through stone, blue. For these tints use respectively yellow ochre, carmine and Prussian blue. This process is better and much more expeditious than cross-lining or "hatching." The parts that are cross lined in the illustrations should be tinted by the student in his drawings.

CHAPTER I.

Plans.

As the arrangements of the principal living portions of the house are of primary importance, we will give attention to the first and second story plans before drawing that of the basement or giving particular thought to the elevations.

First Story—Fig. 3.

Walls.—In laying out any floor plan, begin with and complete the outer walls regardless of door and window openings. In this story, these are what are called 13″ walls, being in thickness the united width of three bricks, each 3″ wide, plus two mortar joints each ⅜″ thick. This gives a total of only 12¾″; however, 13″ is sufficiently exact at the small scale we are using.

As the kitchen addition is to be but one story high, we must either build up entire from the basement a wall for the second story on the east, or carry the upper portion of such a wall by some means. This latter is preferable, and can be done quite simply by the use of steel I beams supported on stub walls, as shown. These stub walls will reduce the span of the beams and at the same time will give a continuous inner wall on which to raise the service pipes for the bath room.

In like manner we will carry the wall above the dining room bay.

Furring.—A brick wall is somewhat porous, hence precaution must be taken against possible dampness coming through which would endanger health and deface the plastering. On the inner face of the brick walls strips of 1″x2″ stuff placed vertically (16″ centers for convenience in lathing) are nailed flat to laths or wall plugs set in every seventh joint of the brick work. This is called furring. The furring receives the lathing and upon the lathing the plaster is spread. See Fig. 17. Thus, excepting about the chimneys (which are not furred in this way, if at all), we must add 2″ on the inside to the thickness of our walls.

Windows and Doors.—Next, cut the wall openings. Note in the elevations shown in Figs. 9, 14, that the windows in the different stories, in general, are in sets, centered on common vertical axes. This arrangement harmonizes with the "lines of the building" and is usual even though the openings be unlike in width. Were they placed at random, the exterior effect would be very bad. In cutting the windows, then we must check their centers, seeing that these align with the centers of like openings in other stories. In masonry walls, the width of these openings, of the

intervals between them, and of the doorways must be stated. In setting such distances off on the plans do so cumulatively—i. e., add each successive one to the sum of the previous distances from the starting point. This method is a sure check on the general dimensions for the "sum of the parts equals the whole."

For clear window openings allow 8″ more than the marked width of the glass—i. e., 4″ each side for the window frame and sash in addition to the width of the lights. On the plates, the numerator of the fraction indicating the size of the lights is the width, the denominator is the height of the glass.

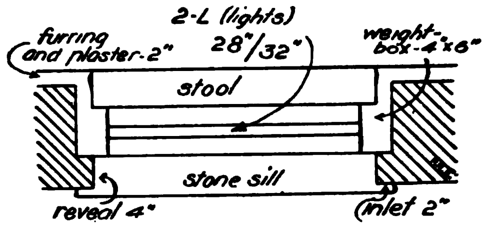


FIG. 4

No attempt should be made to show a true projection of the weight box, window frame and sash at this small scale. All that is required is that they be indicated by some well understood conventional method as shown in Fig. 4.

For a doorway, allow 4″ more than the stated width of the door—i. e., 2″ additional each side for the door frame.

Sills.—The stone window and door sills we will allow to project 1″ from the face of the wall and will insert them 2″ into the wall at each side of the opening, thus making them 4″ longer than the opening is wide.

Partitions.—As the partitions are always set up before any plastering is done, it is good practice to locate them on the plan by the distances from their center lines to the inner face of the brick walls with which they are parallel. Also, intermediate parallel partitions should be thus established in reference to each other—i. e., by the distances between their respective center lines. Always see that the sum of the distances between the walls and centers of partitions, taken across the building, plus the thickness of the walls, is equal to the outside dimensions of the building, taken in the same direction.

For the thickness of an ordinary partition, allow 6″, made up thus: studding 2″x4″, set edgeways, plus 1″ each side for lath and plaster. The partition for the sliding doors is made up of two rows of studs 2″x3″, set 4″ apart, is lined inside with ½″ stuff, and plastered outside only; total thickness, 12″.

Chimneys.—The laundry chimney flue, with opening for foul air from the gas stove in the kitchen, is 8″x8″. The others, for the heater and for the fireplace, are 8″x12″, while the fireplace itself is 16″ deep by 2′ 6″ wide. Flue tile or flue lining is required in all good work. This comes in 24″ lengths, is about ¾″ thick, and somewhat less in clear opening than the specified flue openings. Ordinarily chimney walls may be 4″ thick safely, but the wall of a fireplace should not be less than 8″, if of common brick.

Two openings into the same chimney flue should never be permitted. The upper opening will surely rob the lower of its draft.

Stairs.—The stairs are a very important feature of a building, and often much care must be given to their design. A well is left in the floor to which they ascend, and ample head room or clear height between

the stairs and the overhang of this upper floor must be allowed. See Fig. 14. As stair building in itself is quite a distinct branch of joinery, usually the stairs are made at the shop, brought to the building complete, and set up by stair builders.

Risers.—The path that a person would follow in using the stairs within easy reach of the hand rail is called the travel line: its length is the run of the stairs. The travel line is usually assumed at 18″ from and parallel with the rail, or in the center of stairs 3 ft. or less in width.

A riser is the vertical face of a step.

A tread is the top of a step.

On the travel line all treads must be uinform in width, and of course the risers must be uniform in height, otherwise a person would stumble. The whole height of a flight is its rise. The height of a riser must be an exact divisor of the rise of the stairs. To find this, reduce the rise of the flight to inches and divide this distance by an assumed height of the riser. If this quotient be a mixed number, divide the rise again, this time by the whole number nearest to the mixed one just found. The quotient will be the required height of the riser.

For example: From the sectional view, Fig. 9, we see that the total distance between like points of the two floors is 122″. This is the rise of our stairs. Assuming 7″ to be a good height of riser, then 122÷7=17 3/7. Now, 122 divided by 17 equals 7.176, the correct calculated height of the riser. But frequently the architect or stair builder will not lay out his stairs until the rough floors are down. Then he can get the actual rise of the flight, which may vary somewhat from the figured height. This he will divide into as many equal parts as risers are called for on the plans, in our case 17.

Treads.—That the travel may be easy, the treads must be well proportioned to the risers. There are many methods of determining the width of these. Two will suffice. A—Twice the rise taken from 25 equals the tread. B—The product of the rise and the tread to be not less than 70, not more than 75.

In a residence, 7″ to 7½″ is a good riser. According to the first rule for finding the tread, ours would then be 10.65″, but according to the second rule we could use 10″, and we will use that, as we do not want our stairs to extend needlessly into the reception hall.

For cellar and attic stairs, limits of space may require that risers be higher and treads narrower than the rules call for. In practice they frequently vary in these particulars from the main traveled stairs of the building.

Lay down the travel line. Then start from the top and set off the treads thereon. Where the stairs turn, the steps are called winders; on the travel line these must have the same width of tread as the other steps have. Following the above instructions, the student must figure out for himself the other stairs of the building as he comes to them.

Heating.—For a dwelling, heating by hot water is generally conceded to be preferable to heating either by steam or by hot air. It is, however, the most expensive to install and to maintain. Steam or hot water heating is done in two ways, known as the "direct" and "indirect" systems. In the former, the radiators or coils stand in the rooms and the temperature of the atmosphere about them is raised by the

heat of the steam or water passing through them. The air in the room remains unchanged. This is the common method of heating, and suffices excepting in public buildings, such as schools and theaters, where ventilation and heating are combined as one problem. In the latter system, the indirect, the coils are inclosed in a coil chamber into which fresh air is admitted, becomes heated as it passes among the coils, and is discharged through flues into the various rooms. By the suction of exhaust fans the foul air is drawn out through another set of flues, and thus the circulation of pure, heated air is maintained. This method is impracticable and unnecessary in a dwelling.

The catalogue of any heater or radiator firm will give, together with other data, ratings of heaters and methods of calculating the sizes of radiators. These ratings are based on the assumption that the heater, and all flow and return pipes are covered (insulated) to prevent loss of heat. It is enough here to state that for a house so exposed as ours, an allowance of one square foot of radiating surface for each sixteen cubic feet of room space will be ample. Commonly the allowance for bedrooms is not so great as that for the general living rooms. If steam heat were used, one surface foot of radiation to 50 cubic feet of space would be enough.

Taking the ordinary "Italian Flue" radiator as a standard type for hot water, each loop or section is 3½″x10″, and if 37″ high, a much used size, will contain 7½ square feet of radiating surface. The student must calculate the proper sizes for radiators for the second floor. They were purposely omitted.

Radiators should be located in the most exposed parts of the rooms. It is a very general practice to put them immediately in front of windows, but there are objections to this as well as advantages. They never should be housed beneath window seats, as their effectiveness is greatly diminished thereby. If the radiation is distributed as shown, results will be more satisfactory, but the first cost will be more than when it is concentrated.

In construction, the risers for the hot water heating system, together with the water, waste, and soil pipes of the plumbing and sewage systems, are sealed in the partitions. Steam risers are not usually inclosed. The architect need not necessarily be a heating expert, but he should be sufficiently familiar with the subject to enable him to check the calculations of the heating contractor, and to see that the heating system is properly installed.

Miscellaneous.—Plumbing fixtures must be drawn where wanted, gas openings indicated in red ink, the of swing doors given, and special pieces of cabinet work, such as the china closet and the mantel, must be shown.

The usual sizes of common cast iron kitchen sinks are 16″ or 18″ by 24″, 28″ or 30″, 6″ deep. Ordinary oval wash bowls are 12″x14″ or 15″x17″. The smallest slab for the former is 20″x24″. Height of bowl from floor 2′ 6″.

Bath tubs are 4′, 4′ 6″, 5′, 5′ 6″ and 6′ long, the extreme outside length being about 6″ longer than the nominal length in each case. Allow 30″ as the average outside width for all sizes.

Slate laundry tubs come in sets of two or more. A set of two measures 24″x48″ and 16″ deep.

For a water closet allow a floor space 2′x2′ 6″. The closet being about 20″x24″, however.

Dimensions.—In dimensioning the drawings, draw, first in pencil, the extension and dimension lines where needed, allowing ample space for the figures; next, insert in black ink the dimensions and the arrow heads, then ink the dimension and extension lines in red. Such a method or procedure will insure good work in this important particular.

Usually the outer lines are general dimensions, and, naturally, these should be the exact sum of the inner lines or detail dimensions. Check both the calculations and the scaling before inking. Do not "fake in" a correct dimension for a part incorrectly drawn; redraw it correctly. Leave no part to be scaled by the builder that should have a marked dimension. Be accurate and thorough as a matter of principle. For the door schedule make the door numbers black, but the surrounding circle red. Such a schedule is preferable to the quite common practice of putting the dimensions on each door.

Second Floor Plan—Fig. 5.

The outside dimensions of the second floor plan, omitting the rear addition and the south bay, are the same as those of the first floor plan.

The walls of the second story are called 9″ walls, although they are reaily about 8½″ thick and should be so laid out. To this must be added the furring as in the first floor plan.

The east wall we will carry as before noted, on a pair of 9″, 21 lb. steel I beams placed 5″ between centers, bearing on cast iron plates 8″x12″x¾″. In like manner the wall above the dining room bay and the roof above the bedroom bay will be carried. The first ·ill require two 7″ 15 lb. beams and the second two 7½ lb. beams. By I beams is meant beams having a cross section like a capital I. The depth of the beam is the dimension given, and the weight specified is the weight per lineal foot.

The flues from the fireplace and heater we will draw together in the fireplace chimney breast, as shown in Fig. 14, and carry them up vertically from below the line of the second floor.

The roof plans of the kitchen, south bay, and porch, must be shown in this view.

In planning chambers, the openings of windows and closets should be made with regard to the placing of necessary furniture in the rooms. In determining the swing of doors care must be taken that they do not conflict or jam when open, or cut off the light in the case of closets. If the closets are to be provided with shelves and cabinets of drawers, these should be shown in the drawing.

Basement Plan—Fig. 6.

A rubble wall (one of undressed, unsquared stones, laid in random courses) of less than 18″ thickness is hardly practicable, hence ours shall be 18″ thick. These are not to be furred or plastered, although the laundry might well be, and often is. The library chimney we will build of hard burned brick laid in cement mortar, one part cement to two parts sand; then that wall will not require extra thickness because of the flues. The laundry flue will start at the top of the stone work. In locating the posts and girders for intermediate support of the floors and partitions, we will align them directly under the run of the main partitions of the floor above. The joists will then be laid spanning the shorter distances from girder to girder or from girder to wall. The ends of

the cross girders, beneath the west kitchen partition are carried in part on corbels built out on stub walls, thus, Fig. 7, while the cast iron brackets noted on the posts common to two runs of girders are of the design shown in Fig. 8.

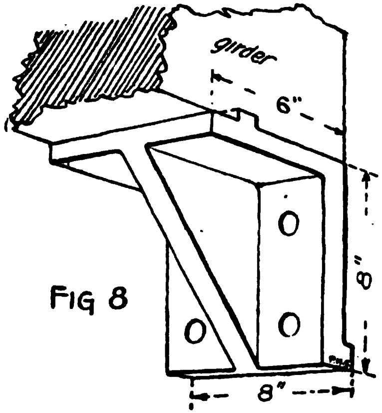


FIG 8

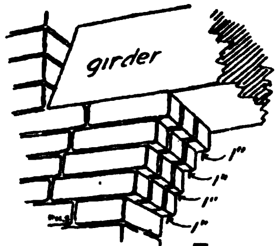


FIG. 7

For windows we will use common cellar sash, hinged at the top, hence without weights, but must allow, as before, for the clear window opening 8″ more than the width of the glass. The frames are of 2″ planks alike for windows and rear door. The window frames are 8″ wide, are placed on top of the stone wall, 5″ from its face, thus giving a 4″ reveal or jamb in the brick work about them.

It must be kept in mind that a building plan is frequently a composite projection of several rather than a literally true projection of one horizontal section taken through the building at a certain level.

To illustrate, a horizontal section through the basement windows, to be true, must needs show a section through the brick wall all the way about the building, but this latter we omit; or if taken below the windows, they would have to be shown by dotted lines. Certain practices of this kind have become established through long usage, and we will make our drawing conform to them.

In our basement plan the underground sewage system must be shown; a plumbing diagram will be drawn later. In such waste and sewer pipes, branches should be at 45 degrees (never 90), and should turn in the direction of the fall of the system. Pipes of this kind, when it can be done, should always be carried beneath the walls below doors and windows, so that the wall pressure on them may be as little as possible. Ink all such pipes in green.

The catch basin receives the drainage from the sinks, tubs, and down spouts only; soil pipes discharge directly into the sewer. This is the law.

This plan must also show the piers for the porches.

The basement should be very fully dimensioned, for from it are established on the ground the breaks in the outline of the walls which may be carried up the whole height of the building.

Roof Plan.

For a roof of such a simple character and construction as that of our house, a roof plan is hardly necessary. However, the student might draw one, so that his plans may be complete.

We will allow the eaves to overhand the projection of the front bay and the library extension, thus giving an uninterrupted cornice line 3′ 6″ beyond the face of the building. In this view, the orthographic projections of the hips are the bisectors of the corner angles.

The gutter, downspouts, and chimney should be shown, and by breaking the roof we might show the framing at the cornice and about the chimneys.

CHAPTER II.

Elevations—Figs. 9 and 14.

Considerations.—An elevation is a simple orthographic projection of the building upon either vertical plane. "Looks" is the first essential in the design of an elevation. The merit of this depends almost wholly upon the knowledge and good taste of the designer. In this particular, "rules" for the guidance of the student can scarcely be formulated. However, a few necessary considerations may be noted. Elevations should correspond with the plans and be supplementary to them, inasmuch as, always, they should be made from these and never the reverse.

In style the structure may be any of the much used but nameless ones well adapted to suburban surroundings, or it may be distinctly Colonial or any other suitable style of historic character. But in all cases the exterior must be uniform in style throughout, the design being in keeping with the building's environment.

The width being already fixed by the plan, a height agreeably proportioned thereto must be determined in the elevation. Prevailing practice settles the approximate height of the parlor and chamber stories. Very high rooms are hard to heat and are not "cozy."

In establishing the grade level, we may set our building down in the ground, or "up in the air," as it were, and the roof we may design wholly to our fancy. The basement we do not wish to have too far below ground lest it be a mere cellar; nor too much above, lest it be cold in winter, and also raise the first floor inconveniently and disagreeably high. We must try to place it just right for good light, good ventilation, convenience, and looks.

Already we have decided to have a hip roof with wide projecting cornice; just as well we might have chosen a gable or curb roof. Figs. 30, 32. We must make it a sufficiently positive feature to be a good decorative finish to the building. It must be neither insignificant nor overwhelming. Here again, appearance is of primary importance. The overhang of the eaves we will set below the ceiling level of the second story, thus reducing the apparent height of this story. This, with the cornice overhang, will help to give our building something of the bungalow effect appropriate to a dwelling amid natural surroundings.

In making the plans, we made mention of the importance of a certain arrangement of wall openings. Now we would add to this: Group or locate the windows, leaving restful, well proportioned, unbroken intervals of wall space between the groups. Properly, some thought should have been given this point in making the plans. Thus, this portion of our problem becomes the pleasing subdivision of our wall space. Above all things, keep the design simple throughout, not permitting the general lines of the building to become "chopped up" by excess of irregularity or the introduction of ill considered variety.

We must finish the kitchen and dining room bay and must design the front porch in harmony with the main roof. In the porch, by omitting one brick column, as shown, we can secure an uninterrupted outlook from the front door and parlor, and can further emphasize the horizontal or dominant lines in our building.

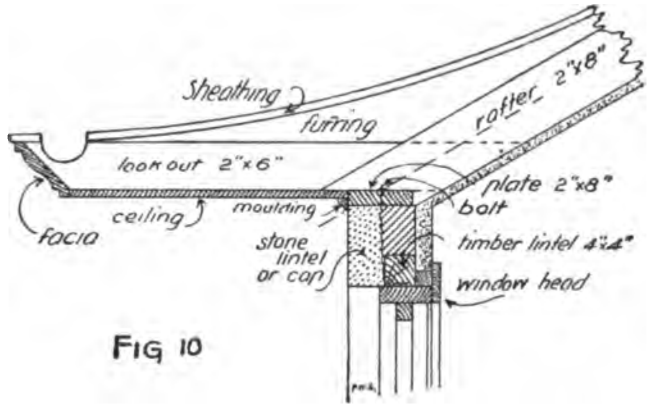


FIG 10

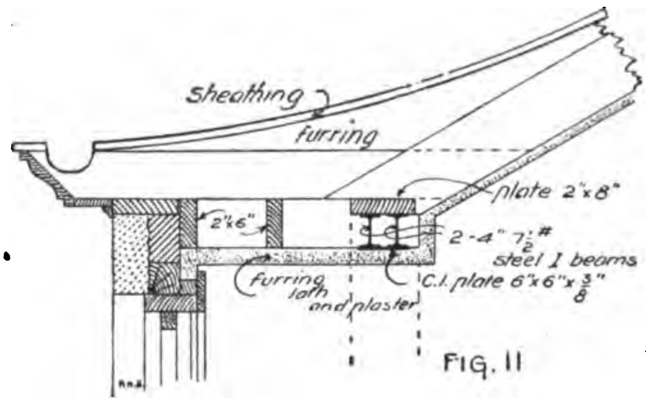


FIG. 11

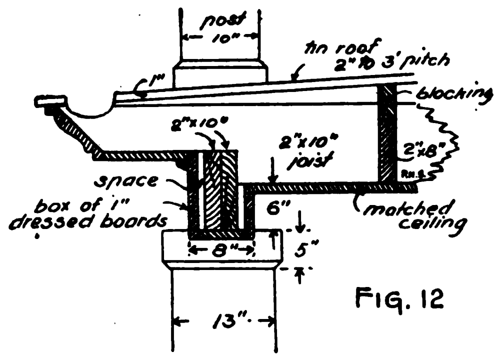


FIG. 12

The decorative details of the cornice and porch the student may design to suit himself.

Because of the minuteness of the detail in the general sectional views, Fig. 9, it is necessary to enlarge the portion at the cornice and at the eaves of the porch as shown in Figs. 10, 11, and 12.

For materials of our house we will use buff brick, with gray stone for trimmings and will paint the woodwork white that the color scheme may be pleasing.

A little perspective sketch of the building, such as is often made by the architect, will give an idea of the merits or demerits of our design. Fig. 13.

FIG 13

The Layout.—The plans show the relative positions and the horizontal dimensions of the rooms, halls and stairs, the location of all wall openings, of partitions, and of the various fixtures, but the heights of the various parts and of the entire building can be shown only in the elevations.

The first thing to be drawn is a "line of heights," or more correctly speaking, a vertical section through the front wall from ridge to footings, which should establish the elevation of the grade (or ground surface) in reference to the footings and to the first floor level, the height of the stories, the position and height of wall openings, and some framing details of cornice, roof and porch. Next it will be a convenience to have a "line of widths" which will show the breaks in the wall line that would be apparent from the front, and on which may be marked the location and width of the openings, this information being taken from the plans.

From these two measuring lines, placed one at the side, the other below, we can by direct projection, easily obtain the essentials and much of the detail of an elevation.

By law our footings must be at least 4 feet below grade, so that they may be beyond danger from frost. The footings should be of good, large, flat stone, well bedded in cement mortar, and the foundation walls resting on them should be of sound limestone, also laid in cement mortar with joints full. This wall should always be cemented all over on the outside up to the water table. At the top of the foundation outside there is a 5″ cut stone water table course (7½″ would be better), which overhangs one inch. From the face of this, the brick wall offsets two inches. The inside offset from the basement wall will then be four inches. There is also a four-inch offset of the second story wall from that of the first store, inside

The story heights are given between joists, and the window openings are located in the same way, as these must be established before any finishing is done. The distances given are from the top of the joist to the top of the stone sill; from the top of the stone sill to the underside of the stone lintel, and from the underside of the stone lintel to the underside of the joist above. Allow for height of window openings 10″ more than the marked height of the glass. Do not attempt detail. Note Fig. 15.

The window sills are 5″ deep with a ¾″ wash (slope on top), while the stone lintels are 10″ deep and have 4″ bearing at each side of the opening. The depth of the stone trim is fixed by the depth of a brick as the unit, and therefore must be a multiple of 2½″, as 5″, 7½″, 10″, etc. Back of the stone lintels are timber lintels, 4″x6″, 6″x6″, etc., to carry the brick work above the frames. This method is more common than the use of a relieving arch in spanning small openings in light walls. We will continue the lintel course across the head of the bays in the first story, and all around the building in the second story.

At the top of the brick wall is anchored a 2″x8″ plank, or bearing plate, on which the rafters bear. The lookouts of the cornice are 2″x6″, and lap the rafters as shown. In the angles are pieces scribed (marked as specified) and cut to the curve of the roof, radius 14′ 6″. The rafters have a pitch of approximately 30 degrees, are notched and spiked to the plates and tied from side to side by the ceiling joists. Over the rafters are laid 1″ common boards, spaced 2″ apart. On this the shingles are laid with an exposure of 4½″ to the weather.

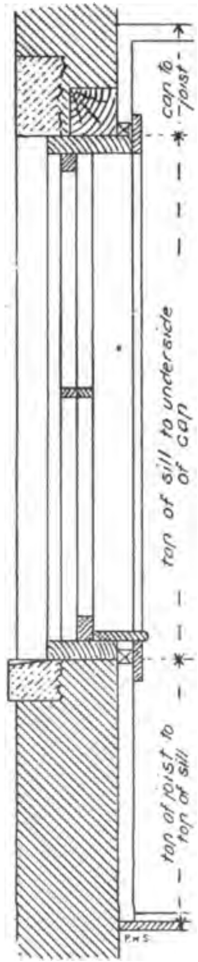


FIG. 15.

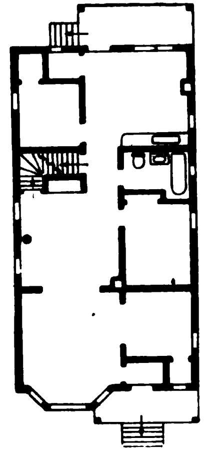


FIG. 16

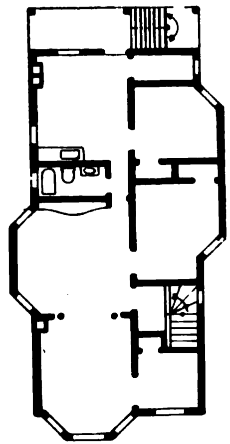


FIG. 16 a.

Where the front bay intercepts the straight wall, the rafters are carried on a pair of I beams. These are furred and plastered, and the ceiling of the bay is dropped to correspond. A gutter having a fall of 1″ in 8 feet is let in on top of the lookouts just back of the facia. The porch floor must be constructed to drain from the wall. A fall of ¼″ in 12″ is usual.

The pitch of tin roofs must not be less than ⅜″ in 12″, but of course may be more. To the porch roof we will give a pitch of 2″ in 3 feet.

In the side elevation it is well to show the head room in the stairways, and the "drawing" or bringing together of the flues in the library chimney.

The ornamental features of the elevation may be worked up to suit the taste of the student.

On completion of the three plans and the front elevation it will be well for the student to undertake working up a set of drawings for a small building, somewhat of his own designing, making the plates of details of construction and of finish accompanying this text as though belonging to his building. With the familiarity already acquired, guided by the explanatory text, an original piece of work will be more profitable than further copying.

Let the problem be either the making of a set of drawings for a one and one-half story brick cottage, or for a two story brick flat building.

The Cottage.—Assume that this is designed for a 25-foot city lot, that it will be open on all sides, however; that it is to have a "one-half pitch" gable roof (see Chapter VI, Fig. 30); that the first story is to be finished but not the half story; and that the first story is to have an arrangement of rooms somewhat but not necessarily as suggested in Fig. 16.

The set of drawings is to comprise a basement plan, a first floor plan, a front elevation with a vertical section through the front wall, and the plates of construction and of finish already referred to. Also a side elevation should be made if time permits. The plans and elevations are to be at a scale of ¼″ to 12″.

In this problem the pupil is to determine the correct dimensions for the foundations, and for posts, girders, joists, etc.

The Flat Building.—Assume that this is for a 30 foot city lot, that it will be inclosed on the sides; that it will have the usual flat roof; and that it is to have an arrangement of rooms somewhat but not necessarily as suggested in Fig. 16A.

The set of drawings is to comprise a basement plan, a first story plan, a front elevation with a vertical section through the front wall, a side elevation if time permits and plates of details of construction and of finish as already mentioned.

The plans and elevations to be at a scale of ¼″ to 12″.

In this problem the pupil is to determine the proper dimensions for the foundations, for the posts, girders, joists, etc.

If we are to calculate the sizes of the various parts of our building, it becomes evident at once that we must give attention to the subject of strength of materials. Original work cannot be undertaken properly without some knowledge of it.

CHAPTER III.

Strength of Materials.

It is hardly within the province of a course in architectural drawing for high schools to enter upon an

exhaustive consideration of the above subject. However, a few general facts, such as may be found in almost any hand book of architecture, now become a necessity to the advancement of our work.

Of first importance in the erection of a structure is its stability. Irrespective of the merits of its design in other particulars, if it is unsafe in construction, the building is of no value.

Obviously, all those parts which are relied upon to sustain the loads of the buildings, or which act as ties in it, must be of sufficient size, beyond all question, to do the work demanded of them. For the calculation of their proportions, certain data are necessary. These we will consider under the headings for the various portions of the structure.

By strength of materials is meant the power of the parts and pieces used in construction (foundations, walls, piers, posts, joists, rafters, rods, anchors, etc.) to withstand the action of the forces, or loads, tending to stretch, to bend, to break or to crush them. The stability of the structure depends upon this power of its members successfully to resist such forces, whether exerted by permanent or shifting loads. In calculating the required strength of these parts or pieces, unit portions or single members, typical of many, perhaps, are dealt with, as will be explained later.

Definitions.

A stress is any force acting upon a part or a piece used in construction.

The safe stress is that stress to which a member may be subjected without risk of failure from any cause.

The elastic limit of a material is the limit to which it may be bent or stretched, for example, and still have power to recover its original shape when the stress is removed. It is usually several times the safe stress.

The breaking stress is the load under which a member will fail.

The factor of safety is the ratio between the breaking and the safe stress; the ratio in which the former exceeds the latter. Unknown imperfections in the materials, defects of workmanship, and precautions against unexpected and excessive demands upon the strength of the pieces require that, for most materials, the maximum safe stress be a comparatively small fraction of the ultimate breaking stress.

For wood, the factor of safety is usually five (5), which means that the load safely carried by a wooden piece should be but one-fifth of the load that would cause it to fail. For wrought iron and steel, the factor of safety is usually four (4); for cast iron, from six (6) to ten (10), and for masonry or concrete, from five (5) to ten (10).

Kinds of Stresses.—Tension or pulling; the stress, if sufficient, elongating the member. Occurs in tie rods, anchors, joist hangers, etc.

Shearing.—The stress, if sufficient, causing one part of the member to slide upon another part. Occurs in riveted plates, in girders and built-up wooden beams.

Tortion or Twisting.—A stress very unusual in architecture, but quite common in machinery.

Compression.—The stress, if sufficient, shortening the member or causing it to fail by crushing. Occurs in footings, walls, piers, studs, posts, and columns, the last three, however, more often fail, if at all, because

of combined crushing and bending stress, or from simple bending, than from crushing.

Transverse or Cross Stress.—A stress such as that exerted by a load on a beam or rafter, tending to bend or break it. The upper fibres are subjected to compression while the lower are subjected to tension.

The formulae used for calculating the sizes of members to resist stresses are the result of very extensive and careful tests and computations, substantiated by years of practical demonstration and expert observation. Further particulars of their derivation do not concern us.

Foundations.—Although the general term "foundation" is quite commonly applied to all that portion of a building which carries the superstructure, or part wholly above ground, here we will use the word to designate only those parts of the building which bear directly upon the soil, and which are often called "footings." And, inasmuch as the basement or foundation walls resting on the foundations are figured in the same way as are other walls, they will not be given special attention.

Foundations, or footings, are invariably wider than the walls they support. The purpose of thus spreading them is to distribute the weight of the building over a larger area of the underlying soil, or "foundation bed," thereby, in effect, increasing the sustaining power of the latter.

Although, of course, it is desired, yet ordinarily the limits of space make it scarcely feasible to design a foundation that would prevent all settlement. Hence, the most that is hoped for is to insure a uniform and substantially neglible settlement of the structure, and thus to guard against the cracking of the walls and other damage.

Before the dimensions of a foundation can be calculated, three facts must be known—namely, the character and the bearing power of the soil, the weight of the structure and its contents imposed upon the foundation, and the material of which the foundation is to be made.

Bearing Power of Soils.—For important, heavy buildings, careful experiments and extensive examinations are made to determine the nature and the bearing power of the soil throughout the site of the proposed structure, and the foundations are then proportioned in accordance with the results of these experiments and the load on the footings, great care being taken to secure relative uniformity of pressure on all parts of the soil.

But such elaborate precautions seldom are taken, nor are they necessary, in the case of buildings of ordinary character, to be located where the general nature of the soil is well known.

Omitting mention of those less common, foundation beds may be classified as rock, solid ground, and compressible or ordinary ground.

Sound rock in a horizontal bed ten or more feet thick will carry a load of from 5 to 30 tons per square foot, depending upon its hardness and other characteristics.

Solid ground includes deep beds of clean gravel; dry, compact sand; and very hard clay. The first will carry from 6 to 8 tons per square foot, and the latter two, from 2 to 4 tons each.

Compressible soil comprises moderately dry and compressible clay, and sand beds, and mixtures of

these or combined with gravel. These are the soils generally met with in Chicago and vicinity.

Of course, soils are never intentionally loaded to their maximum bearing power. The city building ordinances permit the following:

On pure clay bed, at least 15′ thick, unmixed with other material than gravel, 1¾ tons per square foot.

On pure clay bed, at least 15′ thick, dry and compressed, 2¼ tons per square foot.

On dry sand bed, at least 15′ thick, unmixed with clay or loam, 2 tons per square foot.

On a mixture of sand and clay, 1½ tons per square foot.

Practically throughout the city the bed rock is too far down to be reached by foundations other than of the largest buildings. The deep layer of quicksand which lies on it is useless as a foundation bed. Chicago, in a large part, is built upon the stratum of clay which might be said to float above this bed of quicksand.

Weight of the Building.—The loads to be supported by the foundations include the weight of the materials, which, upon completion, form parts of the building, such as those in the foundations themselves, in the walls, floors, partitions, roof, etc., comprising in all what is called the "constant," "permanent," or "dead" load; and, in addition, such a part of the building's contents (termed "live" load) that the floors are designed to carry, as will remain upon them most of the time, also allowance is made in some cases for snow upon the roof and for wind pressure, especially in lofty, exposed buildings.

Table I.—Constant Loads.

	Lbs. per cu. ft.
Masonry of limestone; good rubble in cement mortar	150
Concrete; crushed stone and Portland cement	150
Concrete; cinders and Portland cement	75
Brick work; good common	120
Brick work; pressed brick	130

Weight of common brick wall per square foot of wall surface; including furring, lath and plaster.

9″ thick	90 lbs.	17″ thick	170 lbs.
13″ thick	130 lbs.	21″ thick	210 lbs.

Weights of Frame Parts.

Floors; wooden, double, lathed and plastered beneath:

	Lbs. per sq. ft.
Good, ordinary houses	20
Schools, small churches and halls	25
Stores, warehouses, etc., when plastered	32
Partitions, lathed and plastered both sides, 4″ studs	2C
Ceiling, plastered one side only, 8″ joists	13
Roofs; flat, felt and gravel, good ordinary	15
Gable, shingle or tin	8
Gable, slate	18

Shifting or Live Loads.

Floor Loads.—The building laws require that in addition to the dead weight of the floors themselves, the floors of the various classes of buildings must be constructed to support the following live loads:

	Lbs. per sq.
Residences, flats, apartments, tenements	40
Office buildings, hotels, hospitals	50
Schools	75
Department stores, theaters, halls, churches	100

For warehouses, mills and stables the floors are a matter of special calculation.

Inasmuch as the live loads have no great effect upon the foundation bed when once it has become settled, only in exceptional cases is the whole of it included in the calculation of the footings. As an average, fifty (50) per cent of the live load for which provision must be made by law, is sufficient to include in figuring the foundations for most buildings.

For snow load, in Chicago, allow 30 lbs. per square foot of area covered by the roof if this is so flat that the snow will lie upon it in spite of wind. If the roof is so steep that the snow will not lie thereon, allow the 30 lbs. for wind pressure. Hence, either wind pressure or the weight of snow must be included in the design of the foundations and also in determining the thickness of the walls and the sizes of certain framing timbers. The building code states that "Foundations shall be proportioned to the actual average loads they will have to carry and not to the theoretical and occasional loads."

Computation.—Assume that the proper footings are to be found for a three-story flat building which is to stand on pure clay soil. Let the house be 22′ 6″ wide, 48′ deep, with a basement wall of masonry 5′ high, from which rises a brick wall 37′ high. In compliance with the building requirements for a building of this class and size, the basement wall of brick must be at least 17″ thick, and for the three upper stories, 13″ thick. This will make necessary a basement masonry wall of 21″ thickness. Let the 17″ basement brick wall be 4′ high, the 13″ wall extending upwards the remaining 33′. What width should the footing have? The pupil should draw a vertical cross section of this wall as described and of the footing as it is calculated. Scale, ¼″ to 12″. Depth of footing, 12″.

Now, from the above table, figure the weight of a vertical piece of the side wall one foot wide, and a corresponding strip of the floors and of the roof it carries. In the example, assume that each side wall carries one-half of the load of the floors and of the roof, although, in reality, it does not. Later, the pupil will calculate the load upon the footings for a row of the usual intermediate posts.

	Lbs.
Masonry 1¾′ (thickness) x 5′ (height) x 150 lbs.	1312.5
Brick work 4′ (height) x 170 lbs. (per sq. ft. of 17″ wall)	680
Brick work 33′ (height) x 130 lbs. (per sq. ft. of 17″ wall)	4290
Floors (3) 3x10 1/6′ (½ width of house) x 40 lbs.	1220
Partitions (1 for each story) 3x20 lbs. x 9½′ (height)	570
Ceiling (3d story) 1 x 10 1/6′ x 13 lbs.	132
Roof (flat, felt and gravel) 10 1/6′ x 30 lbs. (with snow)	305
	8509.5

Let S=safe bearing power of the soil per sq. ft= 1.75 tons.

Let W=weight of unit piece of wall, etc.=4.255 tons.

Then W/S=safe width of bearing course of footings in feet=4.255 1.75=2.43=2′ 5″.

If we used 1.5 tons as the value of S, the result would be 4.255/1.5=2.836=2′ 10″, thus giving the footings a greater bearing area because of the smaller sustaining power of the soil. If the value of S was increased, the bearing area would be correspondingly diminished.

When these spread footings are very heavy, because of many courses and of great width, allowance must be made for their weight in calculating their bearing area. In such cases, their weight is added to that of the walls, etc., although in small houses like the one in the example, this is hardly necessary.

If there were numerous large openings in the wall, or a heavy chimney or tower, the footings would be proportionately diminished or increased in width where these are located. As the front and the rear walls do not carry the loads of the floors, partitions and roof, their footings need only be of sufficient size for the weight of the walls themselves. What width should they have? Draw a vertical cross section through wall and footing. Dimension it. Scale, ¼″ to 12″. Depth, 12″.

The footing of a post or of a pier carries the load of a rectangle of the floors, ceiling and roof extending in every way one-half the distance to the adjacent posts, piers or walls. Assuming that there is a row of three posts uniformly spaced and parallel with the side wall, 9′ from one wall, what will be the proper area of their footings? To find this, proceed as in the above example. Make a sectional view of the footing to scale, and dimension it. Scale, ½″ to 12″. Depth, 12″.

Materials.—Footings resting on good ordinary soil are almost always of stone or concrete, for buildings of moderate size.

For the footings on the above building, if dimension stone are used—i. e., large, flat, roughly square slabs 6″ to 12″ thick and the width of the entire footings, one 12″ piece or two 6″ courses would suffice.

These are or should be well settled always, and bedded in cement mortar. Where several courses are required to reduce the footings to the proper width to receive the wall, the projection of the uppermost on each side, beyond this wall, and of each course beyond the next above should not exceed one-half the depth of the course.

Such footings are excellent and are very generally used in Chicago for first class, light buildings, although concrete is supplanting them to a considerable extent and is recommended very highly by some experts for use on soils of uneven density.

If rubble stone masonry is used, such as that in the foundation walls, the footing course should be 12″ deep, the projections of the courses should not exceed one-third (1/3) their depth, and the outer stones of a lower course should extend farther under those of the course above than the amount of projection of their course. Much used for ordinary buildings.

If concrete is used it should be deposited in 6″ layers to the depth of the courses, thoroughly rammed, and no course should project more than one-half (½) its thickness beyond the one above.

Concrete is in reality an artificial rock consisting of crushed stone or gravel, together with sand and cement, mixed dry, then wet, spread, tamped, and allowed to harden in place.

Cements are made either from a certain natural rock, burned and ground fine, giving natural rock cement, or from a mixture of clay and limestone corresponding to the composition of the natural cement rock, burned and ground fine, resulting in artificial or Portland cement. These two are called hydraulic cements, because they will harden under water, to distinguish them from lime cement (lime mortar) which will not.

Cement mortars always should be, and lime mortars never should be used where walls are subjected to dampness.

Very hard burned or vitrified brick may be used for footings of small or of temporary structures, or of interior brick walls on dry ground, being laid in cement mortar, first a double course and then in successive single courses, each projecting but one-half (½) its thickness.

For the foundations of very heavy buildings, it is a common practice in Chicago to drive piles (trimmed tree trunks) long enough to reach "hard pan," to cap them with heavy timbers, and thereon to build the masonry walls.

Also, more recently, our "sky scrapers" have as foundations, concrete piers carried up from bed rock.

Another method of construction is the use of steel I beams laid in transverse courses and imbedded in concrete. This produces a spread footing much more economical of depth and of much less weight than an equivalent footing of masonry.

If the student is watchful he will see work of all the above kinds in progress.

The Auditorium was the last building in the downtown district in which masonry footings were utilized throughout. The Rookery is built on steel rails and concrete. Marshall Field's, the Railway Exchange, the Gas Company's new building and several others stand on concrete piers, while portions of the C. & N. W. Ry. Co.'s new depot have pile foundations.

Arrangement.—"The center of pressure (a vertical line through the center of gravity of the wall or pier) must pass through the center of the footings," otherwise the footings will become tilted, and damage will be done to the superstructure. This is said to be a very important requirement, and undoubtedly compliance with it is to be desired in all cases and is essential in heavy, detached buildings. However, where walls are built adjacent to lot lines it is frequently impracticable to spread the footings on but one side.

Walls.—The city building ordinances fix the thickness of walls for buildings of the different classes and heights, hence these are generally used without special calculation other than in exceptional cases.

Class III includes every building used for a family residence, etc. For these the inclosing walls must be as follows:

	Basement. in.	1st Story. in.	2d Story. in.	3d Story. in.	4th Story. in.
One story building	12	8	...	..	..
Two story building	12	12	8	..	..
Three story building	16	12	12	12	..
Four story building	20	16	16	12	12

By basement wall is meant that above the masonry or foundation wall. The thickness of the latter, if of stone, always should be 4″ more than that of the brick wall resting upon it.

The ordinances permit the substitution of approved concrete walls for those of brick or rubble stone if of the same thickness, and the use of this

material both in bulk and in the form of blocks is daily becoming more general.

Framing Pieces.—Problem.—What should be the size in section of the square posts to be placed in the basement of the flat building, assuming them to be of yellow pine and 7′ long?

The stress to be resisted is mixed compression and bending.

First, what resistance has the material, and next, what force (load) must the posts resist?

Table II.—Safe Strengths—Various Materials—Pounds per Sq. Inch.

	Compression.	Tension	Shearing.	Rupture.
Yellow pine	1000	2000	1200*	100
White pine	625	1400	500*	65
Oak	750	2000	1000*	75
Cast iron	13300	2500	3000	308
Wrought iron	12000	12000	8000	666
Steel	15000	15000	10000	888
Port. cemt. concrete	200			
Masonry	150			
Brick work	150			

*Across grain.

The table shows that yellow pine under compression can safely carry a load of 1000 lbs. for each square inch of section of the piece, the force acting in the direction of the grain.

Now, how is the load on the posts made up?

In calculating the footings we noted that the dead load was the principal factor to be taken into account and that, differing in amount with the various kinds of buildings, only part of the live load was usually included.

In determining the sizes of the framing members, the action of the whole live load upon them must be considered, thus the loads for the posts, girders, joists, etc., will consist of the live loads on the floors, plus the dead weight of the floors, partitions, etc.

In Table I are given the live loads which must be provided for by ordinance in the different classes of structures.

As an example, to illustrate the method of computation, what load will a 6″x6″x8′ post carry?

Let Z=total load in pounds.

Let c=safe resistance of material to compression.

Let L=length of post in feet.

Let s=one side of post in inches.

Then this formula will serve our purpose:

$$Z=s^2\left(c-\frac{12\ c.L}{100\ s}\right)$$

Substituting the numerical values and solving, this becomes

$$Z=36\left(1000-\frac{96000}{600}\right)=30240\ \text{lbs.}$$

If the calculated weight of the floors, etc., was somewhat in excess of this amount, the next larger stock size post, 6″x8″, would be used without further figuring. If the load on the posts was less, but not greatly so, the 6″x6″ would be used.

Now find the actual load on the posts of the flat building. Make a diagram showing the rectangle of the floors supported, assuming that there is a trans-

verse and a longitudinal partition on each floor section. Include the third story ceiling (but not the roof), and add the live load required by law. Then, by the use of the formula, determine the size the posts should be in section.

Problem.—What should be the correct size of the girders resting on these posts and supporting the floors above?

In this case, the resistance of the member is to transverse stress. The loads are made up as in the previous problem, and are the same in amount.

There are several ways in which a beam may be loaded, and the formulae vary in accordance therewith. The most common is that where the beam is supported at both ends and its load is distributed uniformly over its whole length, as in this case.

Let x=unknown depth of beam in inches.

Let L=span of the girder in feet.

Let Z=total load in pounds.

Let b=breadth, assumed.

Let A=safe load of a unit beam 1″x1″x12″=100 lbs. for yellow pine.

The formula for a rectangular beam (any material) so loaded is:

$$x = \sqrt{\frac{LZ}{2bA}}$$

Assuming the value of **b** as 6, by use of the formula find the correct size for the girder, if of yellow pine.

This formula may be used to determine the size and the spacing of joists, both ordinary and special ones like headers and trimmers, and those under partitions. First find the load on any one joist, assuming the spacing and breadth, then find the proper depth of joist to carry that load.

Problems in Shearing and in Tension are ordinarily even more simple of solution.

In the first case, the section area (A) of the piece subjected to shearing stress, multiplied by the safe shearing strength (s) of the material of which the piece is made, as shown in Table II, will give the safe resistance (Z).

Or, vice versa, the total force (load) to be resisted (Z) divided by the safe resistance (s) of the given material, will give the correct sectional area (A) of the given piece.

Thus $Z = As$ or $A = Z/s$.

In determining the tensile resistance required in a member, the algebraic formulae are identical with the preceding ones, but the numerical value of **s** is that shown in Table II under Tension.

Thus, for a rectangular bar, $Z = As$, while for a round bar, inasmuch as $A = 0.7854d^2$ (d=diameter), the formula is $Z = 0.7854(sd^2)$.

Although there is not much occasion to figure the sizes of posts, studs, rafters, hangers, etc., for houses of such simple construction as residences and flat buildings, where the loads are uniform, inasmuch as their dimensions have become well known through long usage, and may be found in the tables of architectural hand books, yet the architect must know how to calculate them as well as how to solve other more complicated problems arising in complex structural work.

Metal Construction.—As will be set forth in the pages on Structural Iron and Steel, these metals have supplanted wood to a great extent as materials for the structural members of large buildings.

Owing to the varied and peculiar shapes used, the formulae for finding the strength of metal members are usually much more involved than those for wood. Furthermore, inasmuch as most of the pieces used are of standard shapes rolled by the large steel mills, the architects depend almost wholly upon the tables given in the descriptive manuals issued by these companies, in determining the proper sizes of plates, beams, columns, etc. Hence, the use of the formulae is resorted to only in exceptional cases.

A copy of one of these publications, that of the Carnegie, the Cambria or other steel company, should be available for reference, likewise a copy of Kidder's Architects' and Builders' Handbook, and also a copy of the city building ordinances. As occasion arises the teacher should explain the uses of the various tables therein contained.

Reinforced Concrete.—Although long known that concrete in which are imbedded metal strengthening rods and bars could be utilized for all manner of building purposes, it is only during the last ten years that this reinforced concrete construction has been so well understood as to bring it into very extensive use.

Its value depends upon the fact that the concrete adheres so closely to the metal reinforcement that they together form in reality one structural mass.

Entire buildings are now erected of this material, walls, columns, girders, and floors, the last being one of its chief uses, aside from foundations, however.

But although so very generally employed, really this form of construction is yet in an experimental stage and the data relative to it are not altogether reliable.

CHAPTER IV.

Details of Construction and of Finish.

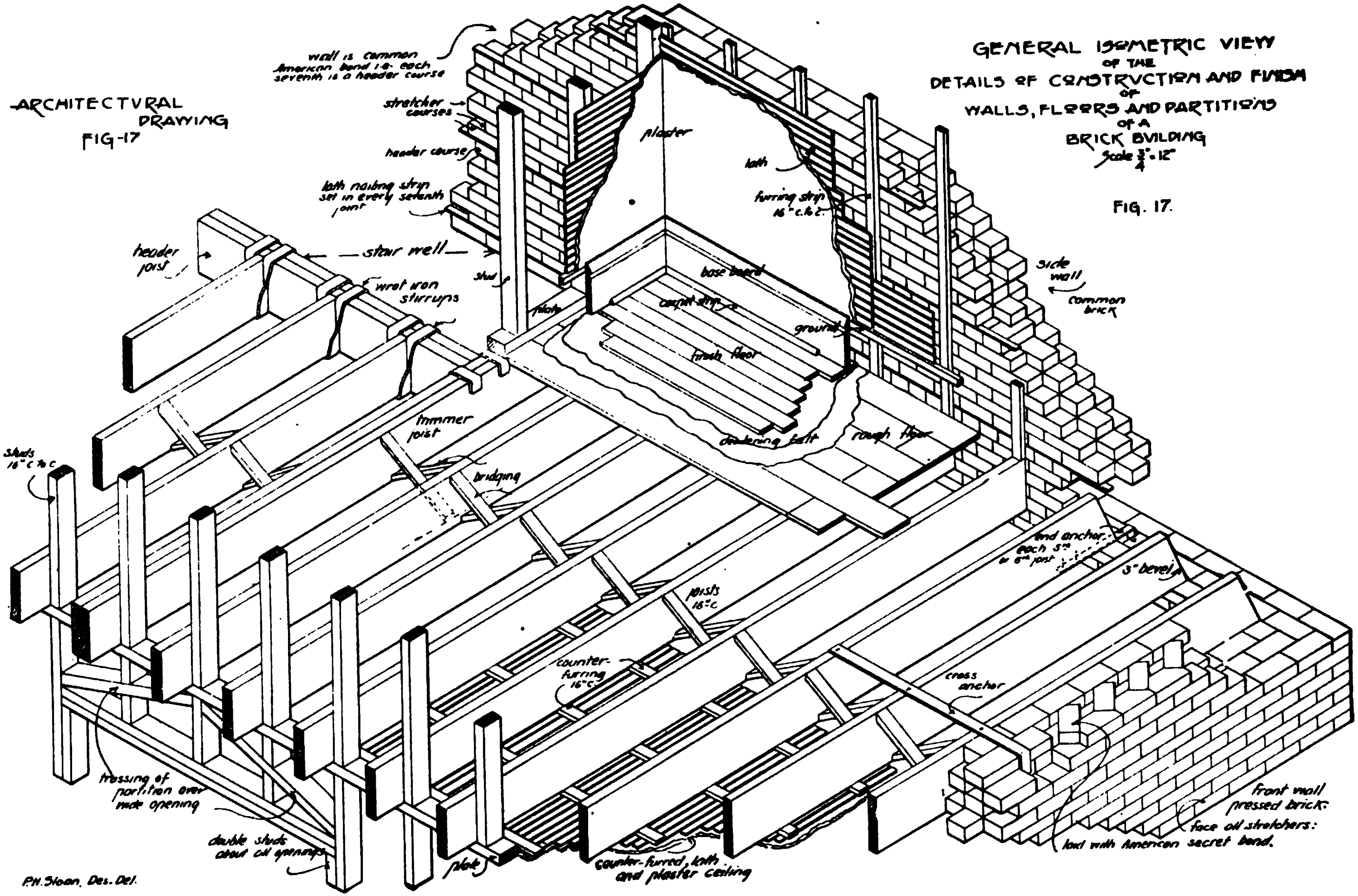
It is not customary to make detail drawings showing the methods of construction except in cases where something unusual occasions the need of them. However, the architect must be familiar with what is known as "good practice," and must see to it that this is complied with. But the student should learn how the walls are built, the framing done, and the finish applied, and he can do so in no better way than by making drawings of these.

The masonry of a building comprises the stone and brick work of all kinds.

The carpentry might be considered its internal skeleton, for it is seldom visible when completed. The joinery is the wood trimming to the dress of the plaster which covers the carpentry.

Figure 17.—This figure gives a general isometric view of the usual construction of the walls, floors, and partitions of an ordinary brick house.

Walls.—To become a solid mass when done, the brick in the different courses must be bonded together in the laying by an occasional change of arrangement. The method shown here is the common American bond. In it, every seventh course is composed of headers, or bricks laid flatways side by side across the wall, the intermediate courses being made up of stretchers laid with broken joints. The adjacent walls are bonded together at the corners by alternate lap-


ARCHITECTURAL DRAWING
FIG-17
GENERAL ISOMETRIC VIEW OF THE DETAILS OF CONSTRUCTION AND FINISH OF WALLS, FLOORS AND PARTITIONS OF A BRICK BUILDING
Scale 3/4" = 12"
FIG. 17.
wall is common American bond i.e. each seventh is a header course
stretcher courses
header course
lath nailing strip set in every seventh joint
header joist
stair well
wrot iron stirrups
stud
plate
plaster
lath
furring strip 16" c. to c.
base board
carpet strip
ground
finish floor
deadening felt
rough floor
side wall
common brick
trimmer joist
bridging
studs 16" c to c
joists 16" c
end anchor each 5th or 6th joist
3" bevel
counter-furring 16" c
cross anchor
trussing of partition over wide opening
double studs about all openings
plate
counter-furred, lath and plaster ceiling
front wall pressed brick: face all stretchers: laid with American secret bond.
P.H. Sloan. Des. Del.

ping of courses. In large structures, bond irons are used sometimes for this purpose. When a wall is faced with pressed brick (as the front wall in the illustration), it is usual to lay the face brick in courses of stretchers only; hence the pressed brick facing must be bonded to the common brick backing either by the method here shown, or more often by little wire ties or crimped pieces of sheet metal laid flat in the mortar joints.

Header courses for bonding in this kind of work are employed by some architects.

Joists.—Floors and ceilings are supported by joists, one end of which, often both, rests in the brick work. Such ends, to comply with the building regulations, must be cut off slanting, so that in event of fire the joists may fall with the collapse of the floor without upsetting the wall. Their usual bearing is about 4″, and the bevel of the end is 3″.

That the opposite walls may be tied together, every fifth or sixth joist should be anchored at its outer ends by means of iron straps with ends turned down and imbedded in the wall, or passed through and bent around a transverse pin outside. Improperly the anchors are often spiked on the top, thus preventing the ready fall of the joists when burned. When the joists are parallel with the wall, the anchor is fastened across the top of several, as shown. When joists meet on an inner bearing partition, their ends should lap fully 12″, and they should be solidly spiked together. To make the floor rigid throughout and to distribute its load, bridging is used, this consisting of pieces (2″x2″ or 2″x4″) set diagonally between joists, and their ends nailed firmly thereto.

About the openings for stairs, fireplaces, and chimneys, where the laying of joists to the wall is prevented, special framing is resorted to. The joists at each end of the opening, called trimmers, are doubled. Hung between them in stirrups, forming the side of the opening opposite to the wall, is another double joist called a header. The ends of the intermediate joists are then hung on this header in like manner, by stirrups. Although by no means the only way of supporting joists, this is one of the best, for the strength of neither member is impaired by cutting.

Partitions.—The frame work of a partition is of studs set on one plate and topped by another. Studs are usually 2″x4″, excepting in buildings where the clear height of the story is more than 10 feet, or the floors are heavily loaded, then 2″x6″ are used. Studding should be doubled about openings, and should be trussed or braced above them, so that the head of the opening cannot sag. When it can be done, the studs of an upper partition should stand directly upon the plate at the top of the one below it (which should then be doubled), and so on down to the girder in the basement. This will prevent much of the skewing of door frames, and the sinking of floors, etc., due to shrinkage which occurs when partitions so located rest on plates laid on top of the joists. Set other partitions on 2″x6″ plates laid on top of the rough floor. For a transverse partition, put a row of bridging beneath it to strengthen the floor if necessary. If it is parallel with the joists, these may be spaced so as to carry the partition, the one directly beneath being usually doubled. To stiffen a partition, braces are set between the studs as shown in Fig. 19.

Furring.—As before stated, brick walls are furred by mailing 1″x2″ strips, placed vertically 16″ between centers, to laths or wall plugs set for the purpose in the face of every seventh joint of the brick work. Frequently the underside of joists are counter-furred, the purpose being to make the plaster more secure against jars of the floor above than if spread on the lath nailed directly to the joists, as is commonly done. Also this construction helps to deafen the floor.

Lathing.—Laths are ⅜″x1¼″x4′, and are spaced ⅜″ apart, with joints broken every sixth course or oftener. The spacing of joists, studs and furring at 16″ centers is to facilitate the lathing, a lath spanning three such intervals. Where increased strength of wall or floor is necessary, 12″ spacing is equally convenient. Lathing must never be carried through partitions at angles.

Grounds.—Wherever "trim" is to be set to finish up about openings and near the base of walls, a "ground" to which to nail it must be provided. This is merely a strip of 1″ stuff fastened to the studding, placed where needed, and also acting as a stop to the lath and plaster.

Plastering.—The first or "scratch" coat is spread —pressed firmly on the laths until it is forced through the spaces, bends over and becomes thoroughly "keyed." Over this in three coat work, a "body" coat is then spread and "trued up." The finish or "skin" coat is then surfaced on this. Three coat work is best, but for side walls two coat work is common and quite satisfactory.

Wainscot.—It is quite a general practice to omit the plastering from the lower portion of walls of kitchens, hallways, and bath rooms, to a height varying from 2′ 6″ to 5′ 0″, and to cover this with beaded ceiling set vertically, panelling, etc. This is called wainscot. The plastering should not be omitted. The stairways, halls, and dressing rooms of the schools are frequently wainscoted. In a similar capacity, cement and glazed tile are much employed on the walls of vestibules and bath rooms. Filled burlap, glued to the smoothed surface of the plaster, is now in very general use as a wall finish.

Floors.—The rough or first floor is of common dressed boards ⅞″x6″ or 8″, securely nailed down. On this a couple of layers of deafening felt should be placed to prevent the passage of sound. Then the finished floor of selected, matched material in narrow widths, Georgia pine, maple, oak, etc., is laid and finally the top should be planed smooth. Tesselated floors, made of small unglazed tile or mosaic, laid in cement in checker patterns are much used in vestibules and bath rooms.

Basement and area floors should be of cement, although the former may have a wood top in parts, as in the laundry.

Baseboard.—About the rooms at the base of the walls is placed a more or less ornamental base board resting on the finished floor, and nailed above to the ground. The base board may be a single piece from 6″ to 12″ high, or it may be built up of several. There is usually some form of carpet strip covering the joint at the floor.

The student will not be required to draw the general view just described, Fig. 17. But he must draw Figs. 18 and 19, which show respectively details of wall and floor construction for a brick building, and details of interior construction and finish suitable alike for a brick or a frame building.

The Fireplace.—Fig. 20.

Tradition or sentiment always causes us to feel that a fireplace is a necessity in a library; that without it the room would be incomplete. Therefore, as it is one of the most attractive problems in the scheme of constructive decoration of the interior of a building, we will not break with tradition or ignore sentiment, but will design a fireplace for our library.

Start the chimney in the basement, it to contain the heater flue, an ash flue for the fireplace, and a blank flue. This latter is built to save brick and in order that our chimney may be symmetrical from the footings up, and yet may not overload them, thus requiring an increase in their size.

The method of framing the floor about the chimney already has been explained, page ——. No joists, in this case the headers, should be nearer the chimney breast than 2″. The trimmer is set back therefrom the width of the hearth, and to it from the chimney breast is turned a brick arch on a "center" built between the headers. The hearth is laid on this arch.

The fireplace opening we will make 2′ 6″ wide by 2′ 2″ high and 16″ deep, from the face brick, which will be ample for the use of soft coal. The back wall should be drawn forward to form a throat behind the front wall.

This throat should have a sectional area equal to that of the flue above; otherwise the draft will be unequal and the fireplace will smoke; not "draw well," as the saying goes. The shelf at the opening of the throat will check any down draft, and also might be provided with a damper with which to close the opening if desired.

The front wall and the face wall are each supported by a 2″ wrought iron angle bar, and an iron frame trims the opening. This frame is 1½″ inside, and 1″ face and ⅛″ thick.

That the chimney may be centered in the north wall its entire height, it is necessary to "draw" the fireplace and heater flues and to liminate the blank flues. Whenever such work is required it should be shown, if it is not so simple that mention of it in the specification or on the plans is sufficient. As before stated, the chimney is lined with tile of suitable size to assure clean flues. The lining and the floor of the fireplace should be fire brick laid in fire clay cement. For the face or veneer of the chimney and for the hearth, we will use red colonial brick, the two lower and the three upper courses corbeled across the front only, with pilasters at the corners. A fire basket and a pair of andirons will complete our fireplace nicely.

The furring of the chimney breast must be entirely detached from the chimney proper. It may stand on a plate that lies on top of the veneer; also being fastened to the trimmer of the floor above. The lookouts or brackets for the mantel shelf will be fastened to the studs and to the plate. The stools or inner window sills we will continue on a level with the mantel. The mantel and other woodwork of this room we will have oak, weathered finish. To complete the decoration of the room we will cover the walls with dull, old rose, or raw sienna burlap. The top mold of the base we will carry up on both sides of each angle of the room, and return beneath the picture rail, thus securing a paneled effect.

In drawing this plate, the student should design the mantel to suit himself, working out the various views to correspond; scale 1″ to 12″.

Two other problems of this character, inviting artistic treatment, are the front stairway and the china closet.

The Windows.—Fig. 21.—The window frame, consisting of the weight boxes, hanging stiles, yoke or head, and sill, is made at the mill to suit the size of the lights specified, brought to the building and set up in the wall as the brick work progresses. The sash are hung and the trim put on after the plastering is done. Window frames, door frames and sash should be "primed" on leaving the mill.

Our stone sills are 5″ thick and 4″ longer than the width of the openings, are undercut to prevent drip getting to the wall, and have a ¾″ cut "wash" or slope on top. Sills are set with the ends only bedded; a ½″ space is left beneath, running nearly their entire length, which is filled when the wall has set. This is to prevent the sill from being cracked at its center by the load on its ends.

The width of the brick jamb or reveal depends upon how the frame is set, but it is usually 4″, or the width of one brick, measured from back of the hanging stile. The stone lintel carries the face wall above the opening, while a relieving arch, or more commonly a timber lintel (4″x6″, 6″x6″, etc.) carries the back wall.

Although there are many different methods of joining the "trim" and the frame, the one here shown is in accord with "good practice," although the linings are somewhat simplified. The purpose of the pendulum is to prevent the weights from conflicting. It should be hung freely, thus permitting the weights being adjusted through one opening into the box. Very often the pendulum is omitted. Check rail sash are used in all good work and upper sash with extended stiles are better than others. Sash for plate glass and ornamental windows of leaded glass must be heavier than those for common glass. It is not necessary for the architect to make detail drawings of window construction other than in exceptional cases. The proper proportions will be given to the various parts at the mill in accordance with the requirements of the specifications. Sash are usually brought to the job glazed and ready to hang, common stock-size sash being glazed at the mill. Special size sash, and those on work of better grade, are brought to the job, fitted and primed, then, usually, taken to the shop of some glazing contractor to be glazed. Common glass comes single thick (1/16″) and double thick (⅛″) in sizes increasing by inches up to 16″x16″, and thereafter in even inches only. Lights should always be specified in stock sizes, and the best quality—AA—called for.

Ornamental windows are commonly made of pieces of plate glass leaded together in various designs. The student may design those in the reception hall and stairway to suit his taste. The plate just described should be drawn by the student; scale, 1½″ to 12″.

Doors.—Fig. 22.—Panel construction is used in the manufacture of doors to reduce their weight, to prevent unsightly cracks, to make them more pleasing, and because they are less expensive than doors of other construction. The rails are mortised into the stiles; the panels are let into the grooved edges of the rails and stiles, but not nailed or glued.

Door frames and paneled doors, such as are in general use, comprise, with windows, stairs, trim, and special cabinet pieces, what is called mill work—i. e.,

work done at a planing mill or stair and cabinet shop. Such work, done by machinery, is much cheaper and better, excepting that of the very best kind, than that done by hand. For an outside door of a brick building the door frame is 1¾″ or 2″ thick, 6″ to 10″ wide, and rebated on its inner edge for the door. On its outer edge is planted a moulding to match the hanging stile of the windows. The frame is nailed to blocks set in the brick work at intervals, and thus is held in place. Doorways, other than for closets, should always be of sufficient width to permit the passage of furniture, single outside doors never less than 2′ 10″ or 3′; inside doors, 2′ 6″, perferably 2′ 8″.

The frame or jamb for an inside door is 1⅛″ thick, is set within the opening left in the studding for the doorway, has a door stop on its face, and receives the trim or casing on its edges.

For ventilation and light, and often to give height to the doorway without making the door itself needlessly tall, a transom is constructed above the door, separated therefrom by a transom bar. The transom is merely a sash, sometimes fixed, more often hinged, set into the rebated door frame and transom bar The transom bar may be simply of dressed plank, or, if heavier, may be a box somewhat of the construction shown.

Most paneled doors are either of the design of Fig. 23, or of Fig. 24, and are specified as "common beveled five panel door," or as a "horizontal five panel door" with sketch accompanying. Certain much used sizes are carried in stock at the mills. The rails, stiles, panels, and thickness of such doors are of the proportions customarily required. For doors of special design, the architect must provide drawings. Doors of hardwood usually have a core of pine and the rails and stiles are faced with a ¼″ and the panels with a ⅛″ or 1/16″ veneer of hardwood. Inside doors, other than sliding doors, are generally lighter than those for outside use.

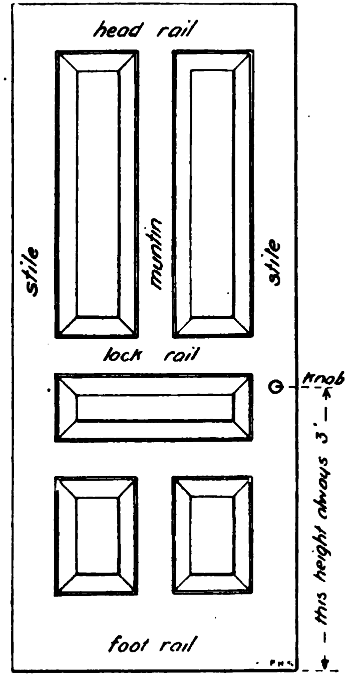


FIG. 23

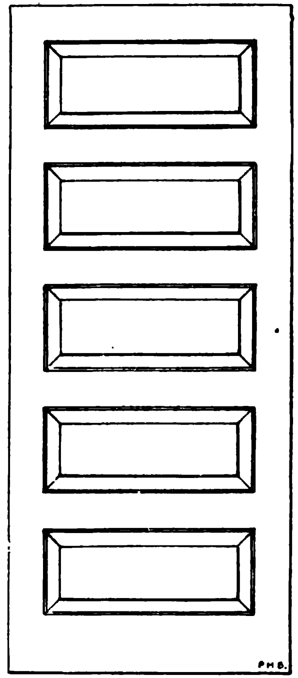


FIG. 24

Sliding doors are suspended from pulley hangers which travel on an adjustable track built in the partition above the doorway. The leaves are usually 6″ or more higher than the other doors, and are somewhat wider than one-half the doorway when the doors are in pairs, as is common.

The trim about interior doors must be the same as that about the windows of the same room. The student must draw this plate.

Trim.—This comprises the door and window casings, the baseboard, wainscot, picture and plate rails, etc. The setting of these with the placing of the special pieces of cabinet work, consoles, china closets, stair rails, window seats, etc., and the laying of the finish floors, complete the joinery of the building.

The faces and edges of the casings are usually more or less moulded for decorative purposes. This result may be secured by building up the trim from several pieces, but more often the trim is one piece and the moulding is worked directly upon it. Mouldings are cut in machines by rapidly revolving knives the edges of which are the reverse sections of the mouldings.

After passing through the cutter, the slight transverse ridges that are evident must be worked down by sand papering. That the edges of the trim may be readily drawn down tight in setting, the back of the wider pieces such as architraves, casings and baseboards, is recessed. These parts, in a residence, are usually ⅞″ thick. Many designs of casings and mouldings are kept in stock at the mills, but special designs are cut to order at a slight additional cost for knives.

Very generally, interior woodwork is given a natural finish. Woods selected for the attractive figure of their grain are used; Georgia pine, cypress, oak, cherry, mahogany and others. To fill the pores and bring out the figure, a wood filler, often containing some color of stain, is applied, then several coats of varnish to protect the wood and improve its appearance.

The finish floor of ⅞″ selected material, maple, Georgia pine, oak, etc., matched, and often end matched, is most pleasing in narrow widths. It should be recessed on the back, be firmly blind nailed, and then planed smooth.

CHAPTER V.

Plumbing and Sewerage.—Fig. 25.

That its pure water supply is adequate, that its drainage is complete and that the source of the former is beyond possible contamination from the latter, are matters vital to the welfare of every city.

The provisions made to secure these necessities comprise the water and sewer systems of a city. They are the creations of the sanitary engineer. Branches of these systems lead into nearly every building; each has its water and sewer systems. And, of so great importance are they, that numerous specific ordinances have been enacted and a rigid inspection is maintained, to the end that these systems shall be properly installed in each structure erected. These regulations, among others, the contractor and architect must know and must comply with. In fact, in each set of drawings upon which a permit to build is asked, there must be a "plumbing diagram," and this must be approved by the proper official before such permit is granted.

Water service pipes are laid from the street main to the curb by the city. From the curb, a licensed plumber must bring the pipes into the building to all necessary points, furnishing and setting all fixtures as shown in the drawings. The size, style and often the make of tubs, sinks, bowls, closets and faucets must be specified by the architect.

Water pipes are of lead, brass, and galvanized wrought iron, the latter being used mainly for hot water. Faucets are of brass, in various finishes. Sinks and laundry tubs are of enameled cast iron and of slate; wooden stationary laundry tubs are forbidden. Bath tubs are of enameled cast iron, but the best bowls, closets and tubs are of porcelain.

Water pipes, with all "traps," sink and tub waste pipes, must be exposed or accessible, adjacent to their fixtures; plumbing so arranged is termed "open plumbing." The sizes, weight and quality of water pipes for different uses are fixed by law, also the methods of setting and of joining them.

The ends sought in the design of sewer fixtures are the quick discharge of all waste, the absolute prevention of sewer gas, and such simplicity of construction and operation as will insure constant automatic cleanliness of the apparatus. Perfection in the make of all fixtures has not yet been attained, but those in use now are vastly superior to those of a decade ago, so rapid has been the advance of the science of sanitation.

Wash bowls, tubs, and sinks are flushed by the water from their faucets, and discharge into a common waste pipe called the "house drain." This, in turn, empties into a catch basin, placed outside the house, or into a grease trap, if the building occupies the whole lot. From the catch basin, the "house sewer" carries the waste to the street sewer.

The catch basin is a necessary receptacle in which grease and sediment contained in the waste from tubs and kitchen sinks may accumulate for occasional removal, which otherwise would harden on the sides of the house sewer and in time close it completely. The water closet is flushed from a tank. It discharges into a "soil pipe," which always empties directly into the house sewer. Other bath room fixtures also usually discharge into the soil pipe. The water closet must be of the type known as "flushing rim bowl" closet.

The sink waste and the soil pipes must be of cast iron, coated inside and out with asphaltum; the joints must be oakum caulked, run with solder and solder caulked in order that they may be air and water tight; if 4″ or more in diameter, they must be provided with a "hand hole" or "clean out," through which they may be rodded; and each vertical line of pipe must be properly supported by floor rests and a footing of brick, stone or concrete. A sink waste cannot be less than 2″, nor a soil pipe less than 4″ in diameter, and with an increased number of fixtures these must be larger.

The house drain and the house sewer must be of vitrified tile or cast iron sewer pipe at least 6″ in diameter, laid with a fall of not less than ¼″ in 12″ toward their points of discharge, and all joints must be filled with Portland cement mortar.

The catch basin may be of brick, concrete, or cast iron. If of brick or concrete, it must be at least 30″ inside diameter; at the top (at grade) it must have a stone or iron cap with cover.

The walls and bottom, if of brick, must be 8″ thick, and must be coated within and without with cement mortar to make them water tight. The bottom must be at least two feet below the invert of the outlet. The outlet must be "trapped" by a hood, to a depth of 6″ below the invert of the outlet, to prevent the escape of grease.

Area and basement drains, boiler and waste drains, and downspouts may discharge into the house drain, the catch basin or the house sewer; the first two must have heavy strainer tops, deep seal traps and back water valves.

The waste and soil pipes are extended up through the roof in order that gases may rise freely from the catch basin and the house sewer, and discharge harmlessly above the building.

The part of the sink waste pipe above the highest fixture is called the "sink vent," and the like portion of the soil pipe, the "soil vent."

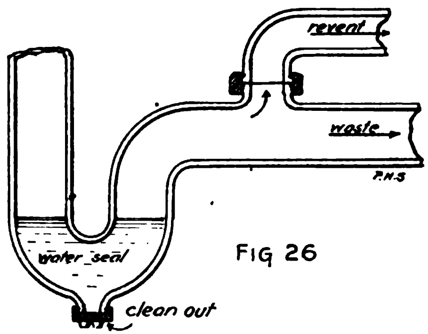


FIG 26

Furthermore, to prevent sewer gases from rising into the house, each waste pipe is so shaped near its inlet that a "trap" or "water seal" is formed, thus Fig. 26. But, by siphon action of the water rushing down the waste or soil pipes (termed "siphonage"), the traps may be almost wholly drained and thus no water seal left. To prevent this a pipe is taken off the waste pipe on the sewer side of each trap and connected to the main vent riser at a point above the fixture. The main vent riser may be reconnected to the soil or waste vent at a point above the highest fixture. This is called reventing. With a few exceptions, such reventing is required of all traps. From kitchen sinks and water closets, these revents must be 2″ pipes, and from other fixtures, 1½″ in diameter.

The bath tub wastes into a "drum trap," having a brass screw top level with the floor, which permits it to be readily cleaned. Sink traps must have threaded brass clean-out plugs at the lowest point of their bends. The increasers at the top of the vents must be 2″ larger than the vents; must begin 12″ below and extend at least 8″ above the roof, and further if necessary. If the vents were not thus enlarged moisture from the escaping gases would condense, freeze and choke them in the winter.

When roughed in, the entire plumbing and drainage system must be tested in the presence and to the satisfaction of the proper city inspectors.

The gas supply pipe is brought in from the street by the plumber, and the piping is extended to all points for fixtures as shown in the drawings. He may be required to furnish the common fixtures, but it is usual for the owner to select and to furnish all others and for the plumber to hang them.

All this work must be done according to the regulations of the gas company, and it must be proved tight by test. Gas, water and sewer pipes under ground must be laid below the frost line—i. e., about five feet below grade.

Painting and Decoration.

All outside woodwork that is exposed must be protected from weather—i. e., action of sun and rain, and all inside wood finish must be protected from smoke, dust, and grease. Other than doors, which are frequently varnished, outside woodwork is always painted. It is first "primed"—that is, given a thin coat of paint consisting of white lead and boiled oil, tinted to suit with oil-ground color.

The second or "body coat" should be heavier and comprise lead, oil, tint, and about 25 per cent of turpentine. The final coat is the same as the body coat, but less turpentine should be used, about 15 per cent only. Each coat must be perfectly dry and hard (not merely set) before the next is applied. Knots and gummy wood must be covered with shellac varnish before the priming is done to prevent the resin from coming out with the heat. Much "fake" white lead is sold, and benzine is used to adulterate or as a substitute for turpentine by unscrupulous dealers.

For painting outside sheet metal, the priming coat should be red oxide of iron paint, mixed with equal parts of boiled oil and turpentine. Additional coats should be the same as for outside woodwork. Metal beams, columns, etc., which are inaccessible when in place should be cleaned and then given several coats of red lead to prevent corrosion.

Comparatively little interior woodwork is now painted, other than that of bath rooms and occasionally chambers. For this, the finest finish is made up of zinc white and demar varnish in turpentine applied over several flat coats of white lead. This gives a porcelain surface. Such paint is called enamel.

In natural finishing, coarse grained woods, such as oak, ash and some kinds of mahogany, must be "filled" first, as before stated, then given a coat of shellac and lastly two or three coats of "side varnish." Fine grained woods like Georgia pine, cypress, cherry and birds-eye maple need no filling or priming; the varnish may be applied directly. The surface may be "gloss," "rubbed," or "wax finish." The first is the common varnish finish; the second is semi-gloss as a result of being rubbed down with powdered pumice; the third is flat and is secured by melting wax in heated turpentine and mixing with varnish. It is the finest finish. Floors are finished in the same way as trim, floor varnish simply being harder. "Spar varnish" should be used for woodwork exposed to water, such as outside doors, inside window benches, woodwork about sinks, tubs, and water closets, as it is not affected by water. "Hard oil" finish is merely linseed oil, boiled down to the consistency of varnish and applied in the same manner. It is a good finish.

Plaster walls are calcimined, painted, papered or covered with burlap or with canvas. For basements and rough work, whitewash is used. Calcimine is made of whiting (powered chalk), glue, dry tint, and water. To prevent lime from coming through and also to enable the easy removal of the calcimine, a "fresco surface" or "sizing" is made of resin in turpentine and applied to the plaster.

Bath room and kitchen walls should be painted. If done over a "fresco" or a "glue sizing," the job will be smoother.

Prepared burlap (filled and dyed) and canvas are hung like wall paper, merely pasted on. The canvas for painting makes the finest of all finishes and permits beautiful decoration.

Miscellaneous.

The rough hardware, which includes sash pulley, sash weights, cellar locks, and hinges and common hooks, is furnished by the carpenter contractor, while the "shelf" hardware, as all that of finer kind is called, that which is exposed to view in the living rooms, such as knobs, locks, hinges, push plates, catches, drawer pulls, special hooks, etc., all of which are more or less ornamental in character, is selected and furnished by the owner, but is set by the carpenter. Electric bells, speaking tubes, screens and storm sash often are included in the carpenter's contract.

The sheet metal work, comprising the gutters, downspouts, the tin roof of the porch and of the bay and the ridge ornament of copper, would be done by the tinsmith.

Various other items and incidentals are likely to require attention in the building of even an ordinary house, and many more in pretentious structures.

CHAPTER VI.

Wood Construction.—Fig. 27.

Balloon Framing.—Light or "balloon" framing is said to have originated in Western New York about 1850. Now, it is the generally practiced method of construction throughout the middle and western states for ordinary frame buildings, although not used extensively in the East.

In the true balloon frame, very seldom any other than 2"x4" timbers or scantling are employed. Upon a plank sill, which rests on the foundation, corner posts best made up of three scantlings are erected. Between these ports the studs are uniformly spaced. At the desired height, the posts and studs are capped with a double scantling bearing plate upon which rest the rafters. The corner posts should be "long braced," as shown, each side of the angle. The studs are spiked to the sill and a joist set next each and spiked to it. If the sill permits, the inner face of the wall should be built up between the joists to the floor level. Fig. 28 shows another method of setting the studs which obviates the objectionable feature in the method just described. The posts and studs extend uninterruptedly from the sill to the roof plate. Thus the upper window openings, by the very nature of the construction, are best placed on the same vertical center lines as the lower openings. In making plans for such frame structures, it is usual, then, to locate windows by the center distances from the corner posts. All studs about these openings are doubled. For the support of the second floor joists a 1"x4" "ribbon," "ledger board" or "bearing strip" is let into the inner edges of the studs. The joists are notched on to this and spiked to the studs, thus tying the opposite walls together. In like manner the ceiling joists of the upper floor are supported and the structure is tied at the eaves. In the balloon frame, the mortise and tenon are not used, the parts being spiked together throughout.

Most frame buildings and many brick, have "gable" or triangular roofs. The spread of such a gable is the span of the roof and the altitude is the "rise." The slope of the roof planes is designated by the ratio of the rise to the span; the first divided by the second, which is called the "pitch." Thus, a roof having a span of 21 feet and a rise of 7 feet is a 1/3 pitch roof,

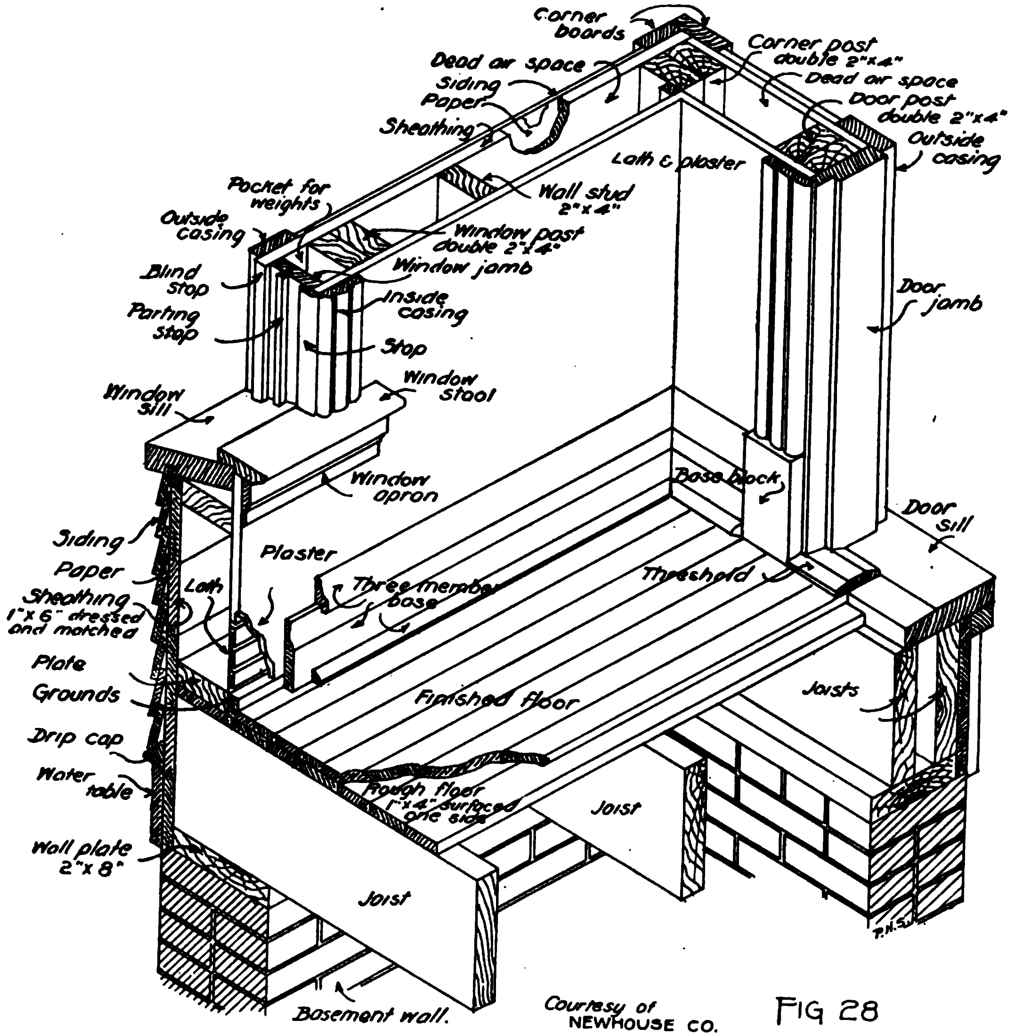

Corner boards
Corner post double 2"x4"
Dead air space
Siding
Paper
Sheathing
Dead air space
Door post double 2"x4"
Outside casing
Lath & plaster
Wall stud 2"x4"
Pocket for weights
Outside casing
Window post double 2"x4"
Window jamb
Blind stop
Inside casing
Parting stop
Stop
Door jamb
Window sill
Window stool
Window apron
Base block
Door sill
Siding
Paper
Plaster
Threshold
Sheathing 1"x6" dressed and matched
Lath
Three member base
Plate
Grounds
Finished floor
Joists
Drip cap
Water table
Rough floor 1"x4" surfaced one side
Joist
Wall plate 2"x8"
Joist
Basement wall.
Courtesy of NEWHOUSE CO.

FIG 28

etc. Roofs vary from 1/6 pitch, and less in some styles of houses, to more than full pitch in some churches. One-half pitch is very generally used for dwellings.

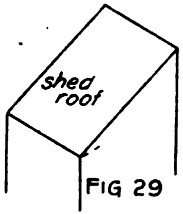


FIG 29

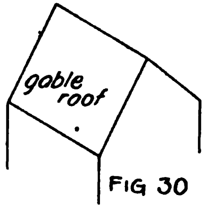


FIG 30

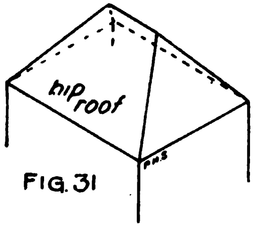


FIG. 31

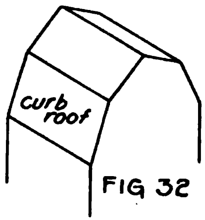
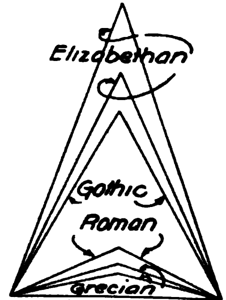


FIG 32

Figs. 29, 30, 31, 32, 33 illustrate other forms of roofs.

The rafters, notched to bear on the plates, extend beyond them to form the eaves. A "ridge piece" should always be placed between the abutting upper ends of the rafters, and the opposing rafters usually are tied together by "collar boards."

"Sheathing"—i. e., common one-inch dressed boards—is placed over the studding, sometimes nailed on diagonally, but more often horizontally. On this is spread a couple of layers of building paper, over which "weather boarding" or "siding" is nailed, as an exterior finish. On the roof sheathing, shingles are laid direct. Frame structures of any kind other than small sheds are not permitted to be built inside the fire limits of our city.



Grecian, 1/7 to 1/9 pitch
Roman 1/3 to [illegible] pitch
Gothic, equilateral.
Elizabethan, full pitch or more.
FIG. 33

"Braced Frame" or "Mill Construction".—Fig. 34, is the old-fashioned or European method of framing. It is still used in the New England States. For certain structures, such as mills, warehouses, stables, and factories, when these are of wood, it is the only safe and suitable kind of construction.

In this mode of construction, the principal members are heavy timbers mortised and tenoned together and thoroughly braced. The lighter parts fill in the panels thus formed. On a heavy sill, large posts are set at the corners and at the ends of each run of inner posts. These rise to the roof plates. Between them, at each upper story, heavy "girts" are framed. The

joists are notched on to these girts while their inner ends rest on post supported girders. These girders are often supported by cast iron columns in place of timber posts. The studding of each story, independent of that of the other stories, is set between the wall and corner posts and is not reinforced about openings as it is in the balloon frame.

The span between walls may be too great to make safe a gable roof of ordinary construction. The roof load must be transmitted to the walls, and a downward pressure upon them must be obtained in some way by neutralizing the great outward pressure or "thrust" of the rafters. These things are secured by means of "trussing" or so framing and tying the roof supports that they counteract the pulling, pushing, and bending stresses upon the members caused by the load of the roof. The resulting frame is called a "truss." Its simplest shape is a triangle. Truss construction is much used for spanning wide openings where the aid of intermediate supports such as columns and piers would be objectionable. The designing of trussed roofs is in the nature of an architectural specialty, important work of this kind being turned over to the Architectural Engineer.

From truss to truss, between the ridge and the roof plate, "purlins" are spaced and laid horizontally.

Upon the purlins, and notched on to them, the rafters are placed. The roof is then finished as in other structures. Often the walls are not finished at all inside.

Outside, the finish may be "drop lap siding," such as is used on many country railway stations, or "barn siding"—i. e., boards set vertically with battened joints.

The floors are of plank joined by dowel strips, and if a finish is wanted, one inch or more of deafening or fireproofing mortar is spread on the planks, then matched flooring is laid over this on bedded strips.

In the city, the walls of such buildings must be brick, no wood furring, laths, or stud partitions are permitted, and elevator shafts and stairs must be of incombustible materials.

Warehouses having brick walls, steel interior framework, and reinforced concrete floors, all absolutely fireproof, are rapidly replacing those of wood construction.

CHAPTER VII.

Structural Iron and Steel.—Fig. 35.

Cast iron and steel have, to a very great extent, supplanted wood as materials for the structural members of our larger buildings.

Iron and steel are stronger and more durable than wood, and the disparity in cost between it and these materials is not so great as formerly, for timber is constantly becoming more scarce, and hence, is increasing in price. And, we might note, the quality of the timber obtainable today is much inferior because it is not allowed time in which to season sufficiently or naturally.

Cast iron is used for columns, lintels, bearing plates, bases, sills, corbels for wood posts, etc. Wood patterns for all cast iron members must be made, or altered to suit, in every instance. From the patterns, sand molds are formed into which is poured the molten metal as for all castings.

Cast iron columns are usually hollow, of comparatively thin metal and are cast around a "core" fixed in the center of the mould. If the core is not placed and kept exactly in the center, the metal will be of unequal thickness on opposite sides of the column and the column will be seriously weakened. The cross section of the column is most commonly circular, but frequently is square or rectangular.

The advantages of cast iron as a structural material are its stiffness, great compressive strength, slight liability to corrosion, high melting point, and consequent ability to withstand extreme heat, and the facility with which it can be cast in any form desired. Its most prominent disadvantages are its slight tensile (stretching) strength, which makes it unsuitable for beams of any kind, and its unreliability. The latter defect is due to the frequent flaws and inequalities which occur in casting, and to internal strains, usually from unequal cooling, which may be such as to cause a large casting to be shattered by a slight blow. These peculiarities necessitate making what is called the "factor of safety" large, in figuring the strength of cast iron, and are responsible for the decrease in its use, especially in large or important work. Cast iron columns should be used only in buildings of moderate height. Cast iron is very suitable and much used for ornamental work in connection with store fronts, stair railings, etc.

Steel members are almost invariably chosen or fabricated from the standard structural sections rolled by all the big steel mills. The commonest of these sections are I beams, channels, Z bars, angles and tees; also flat plates of all widths and thicknesses. Steel columns are almost always built up by riveting together Z bars, channels and angles and plates in various modifications of H and box sections. A new H section is now being rolled especially for use in columns. The heavier of these sections are so thick as to require that holes for rivets be drilled instead of punched, as is usually the case, which adds considerably to their cost.

Beams and girders are generally I beams or two I beams. Channels are occasionally used for roofs and for light work.

For long spans or heavy loads, "plate girders," built up from plates and angles in the form of an "I," or of "box girders," with two or more vertical webs, are used. For spanning large rooms, such as theater auditoriums, deep trusses, similar to bridge trusses, are employed; in this way, many stories can be supported above such rooms without the use of intermediate columns.

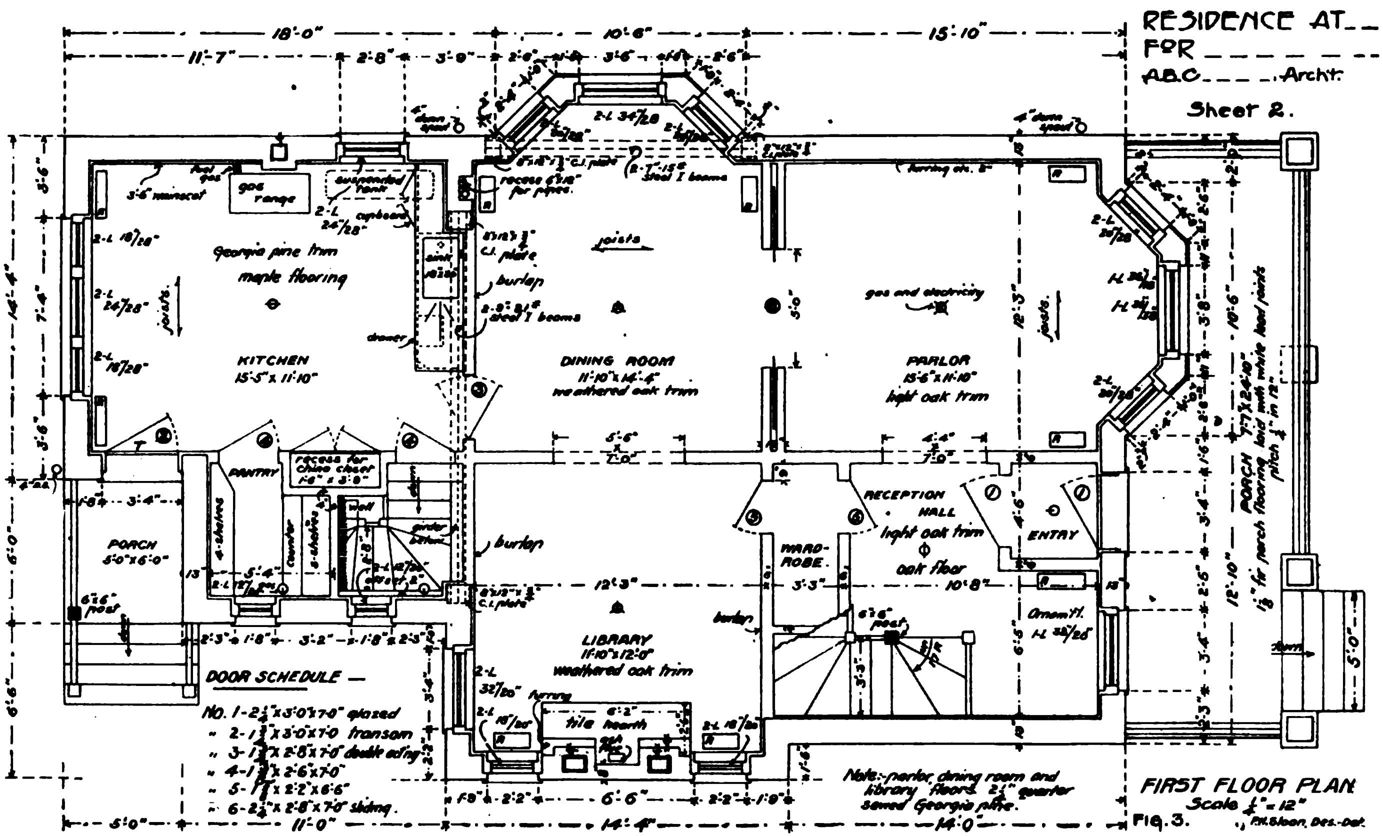
Floors in fireproof buildings are composed of flat tile arched, or of reinforced concrete slabs, supported on steel beams. Partitions are framed with angles or light channels. Tees are used as purlins for supporting roofing and ceiling tile.

In modern tall buildings or "sky scrapers" the entire structure is wholly supported on a rigid steel skeleton, even the outer walls being carried on steel beams or lintels at each story. This form of construction was first employed in our city and is frequently termed "Chicago construction." The Tacoma building is generally conceded to be the first "sky scraper" thus built.

Wrought iron was formerly employed for rolling all structural sections, but for some years has been practically supplanted by steel, which is about one-third stronger. Wrought iron is still extensively used for ornamental work, as it can be bent and "wrought" much more readily than steel.

Unprotected wrought iron and steel are not considered "fireproof," for while they will not burn, they will soften, fail and even melt in a severe conflagration. Therefore, they must be entirely encased, preferably with hollow tile (Fig. 35) or with concrete. While cast iron withstands heat considerably longer than steel, it is not deemed safe to leave it unprotected.

Iron and steel must be kept thoroughly painted to prevent corrosion or "rust." Cast iron rusts very slowly after the first surface corrosion has taken place, but steel corrodes with extreme rapidity and will soon entirely disintegrate if left unpainted. If the metal is to be imbedded in concrete, no painting is necessary, indeed the adhesion of the concrete to the naked metal is much better than if paint were used, but care should be exercised to see that the metal is free from rust when the concrete is placed.


RESIDENCE AT
FOR
A.B.C. Archt.
Sheet 2.
KITCHEN
15'-5" x 11'-10"
Georgia pine trim
maple flooring
gas range
PANTRY
PORCH
5'-0" x 6'-0"
DINING ROOM
11'-10" x 14'-4"
weathered oak trim
PARLOR
15'-6" x 11'-10"
light oak trim
RECEPTION HALL
light oak trim
oak floor
ENTRY
WARD-ROBE
LIBRARY
11'-10" x 12'-0"
weathered oak trim
tile hearth
PORCH
DOOR SCHEDULE —
No. 1-2¼" x 3'-0" x 7'-0" glazed
" 2-1¾" x 3'-0" x 7'-0" transom
" 3-1¾" x 2'-8" x 7'-0" double acting
" 4-1¾" x 2'-6" x 7'-0"
" 5-1¾" x 2'-2" x 6'-6"
" 6-2¼" x 2'-8" x 7'-0" sliding.
Note:- parlor, dining room and library floors 2¼" quarter sawed Georgia pine.
FIRST FLOOR PLAN
Scale ¼" = 12"
FIG. 3.

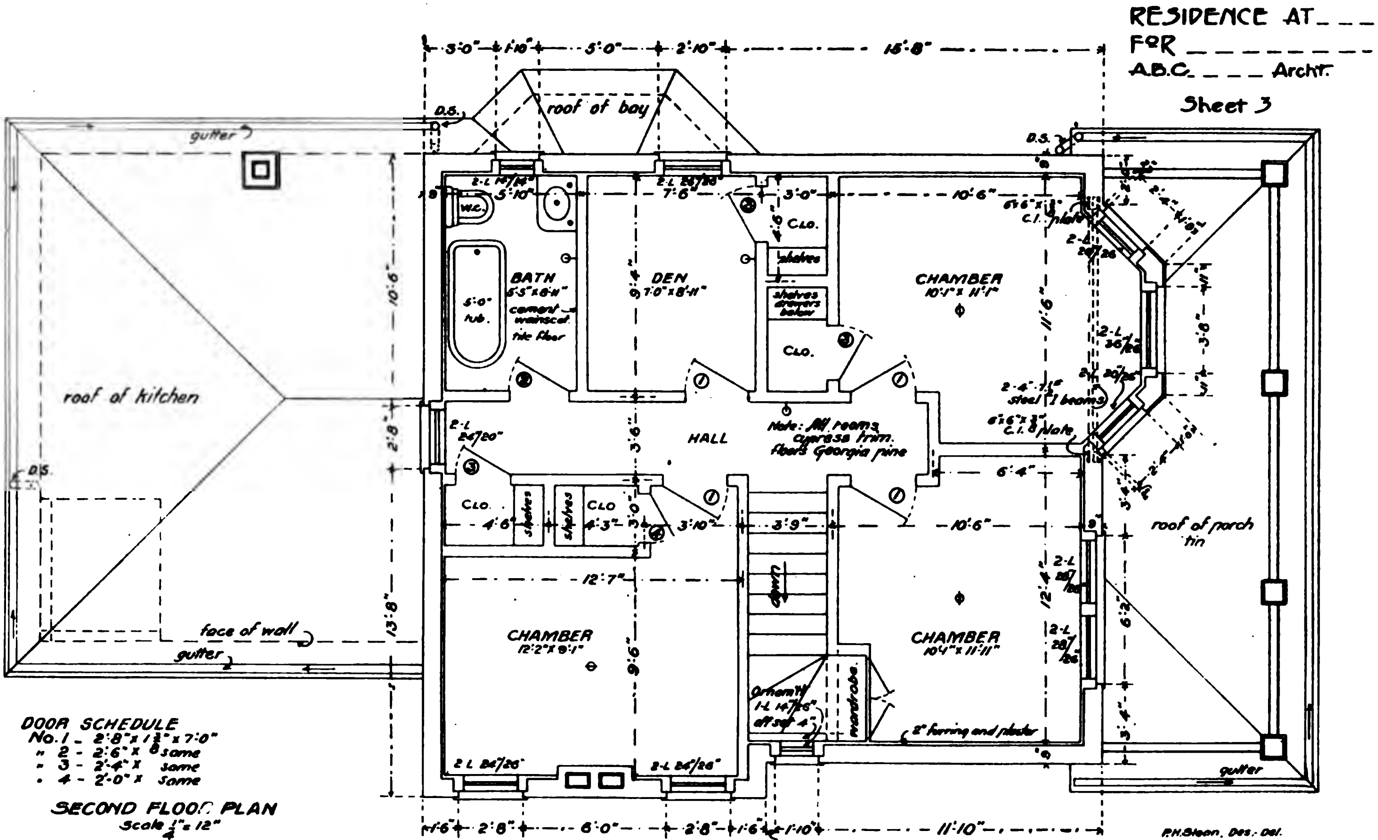
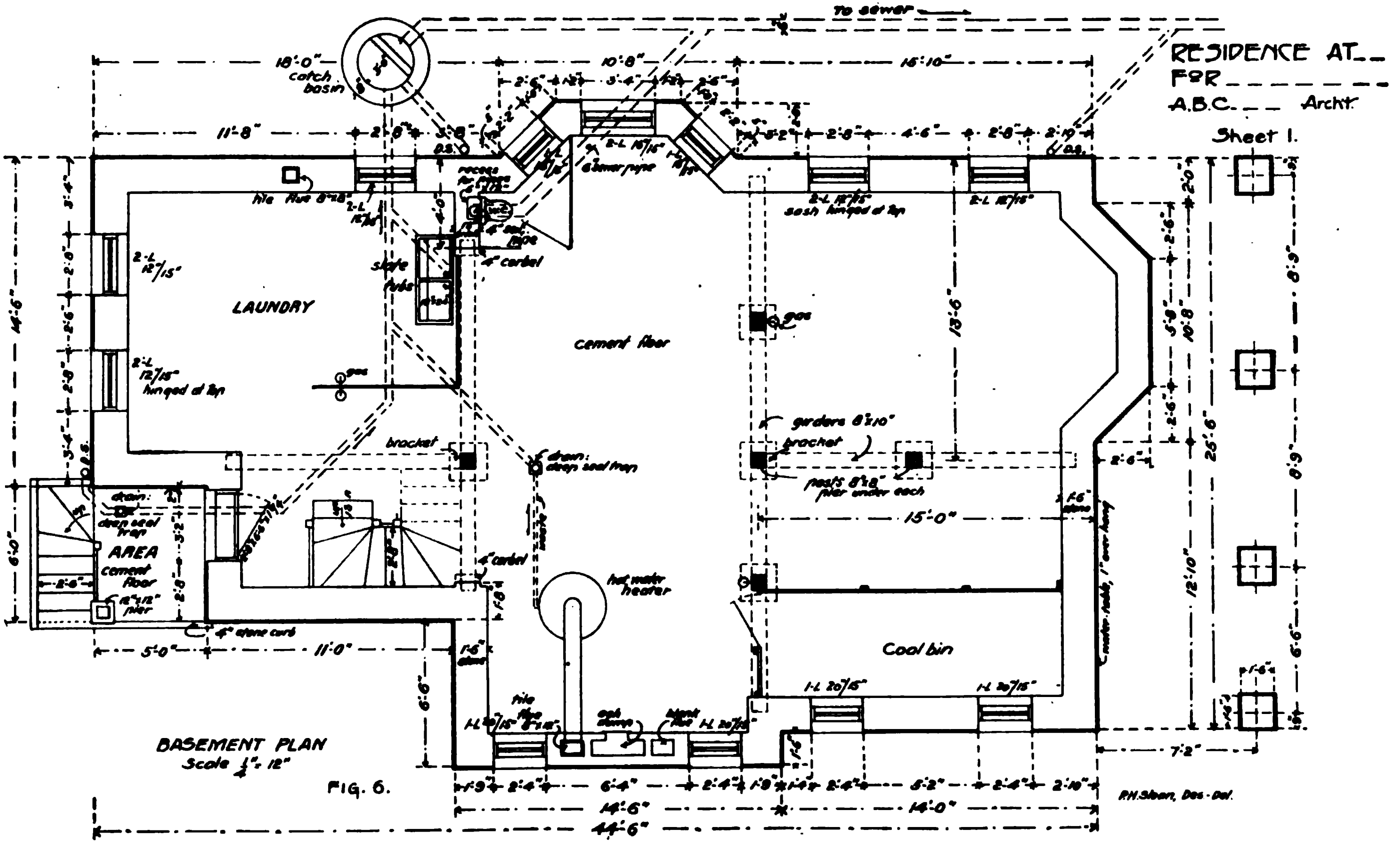


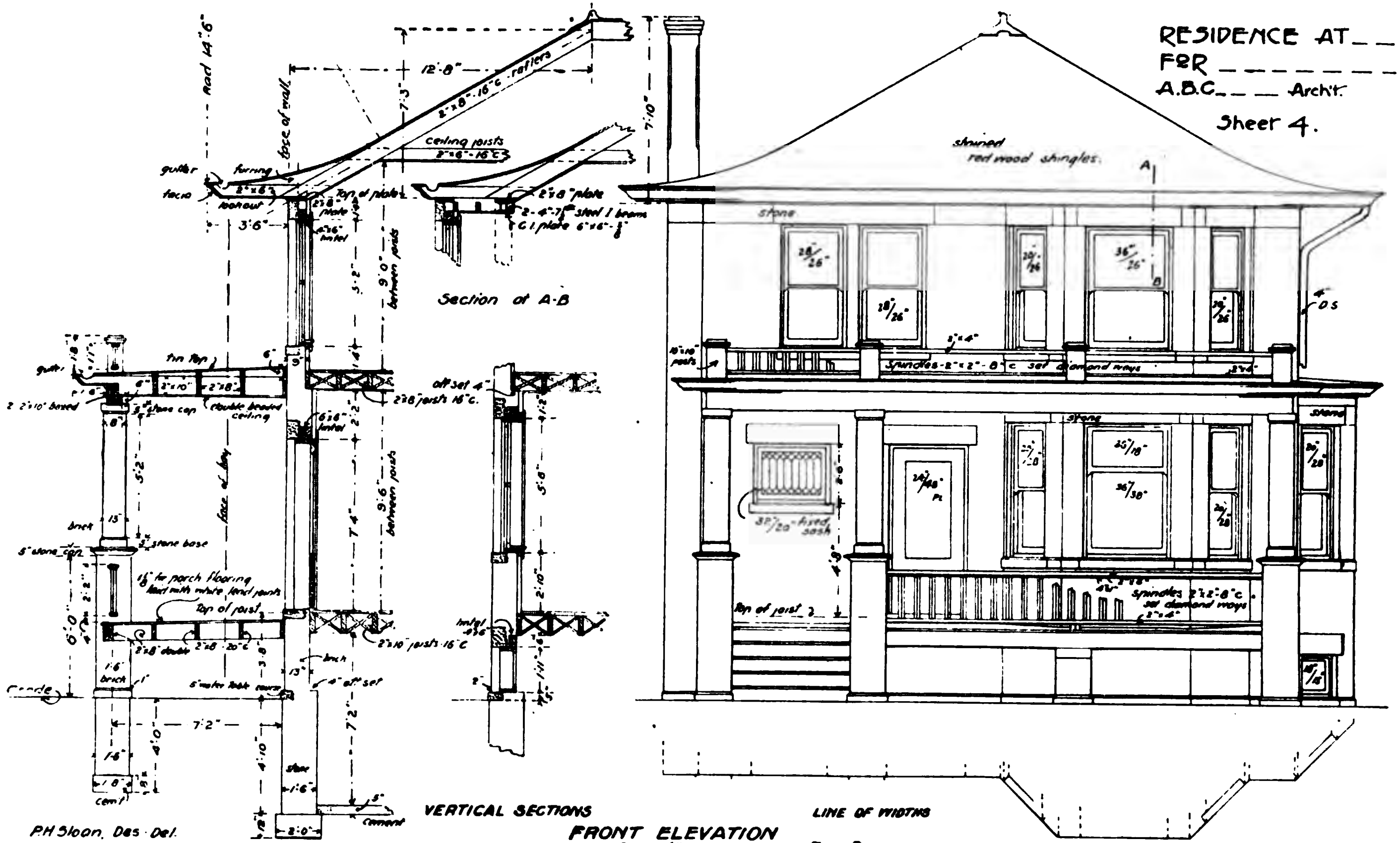
Fig. 5.

Note: Radiators have been omitted from this plan. Student must figure and locate them



BASEMENT PLAN
Scale ¼" = 12"

FIG. 6.



FRONT ELEVATION
Scale 1/4" = 12"

Fig. 8.

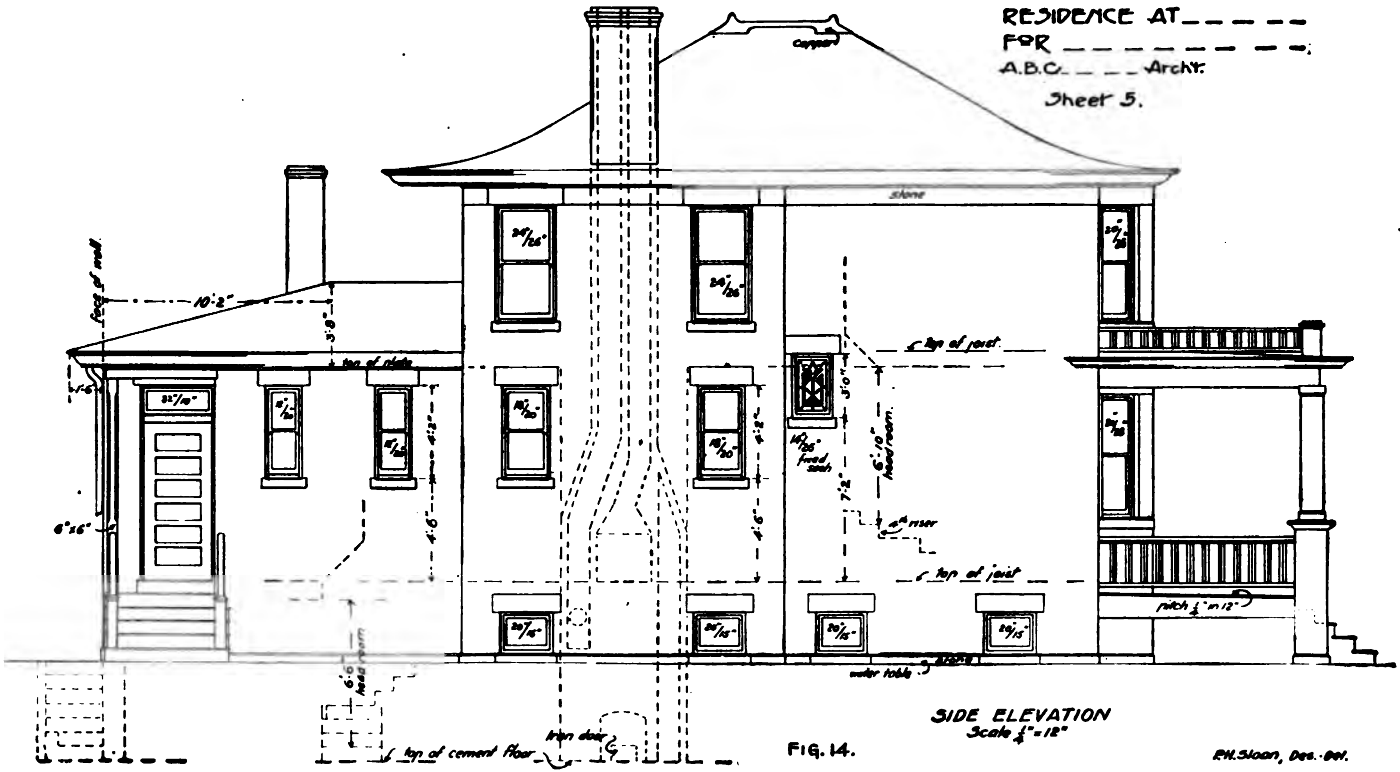
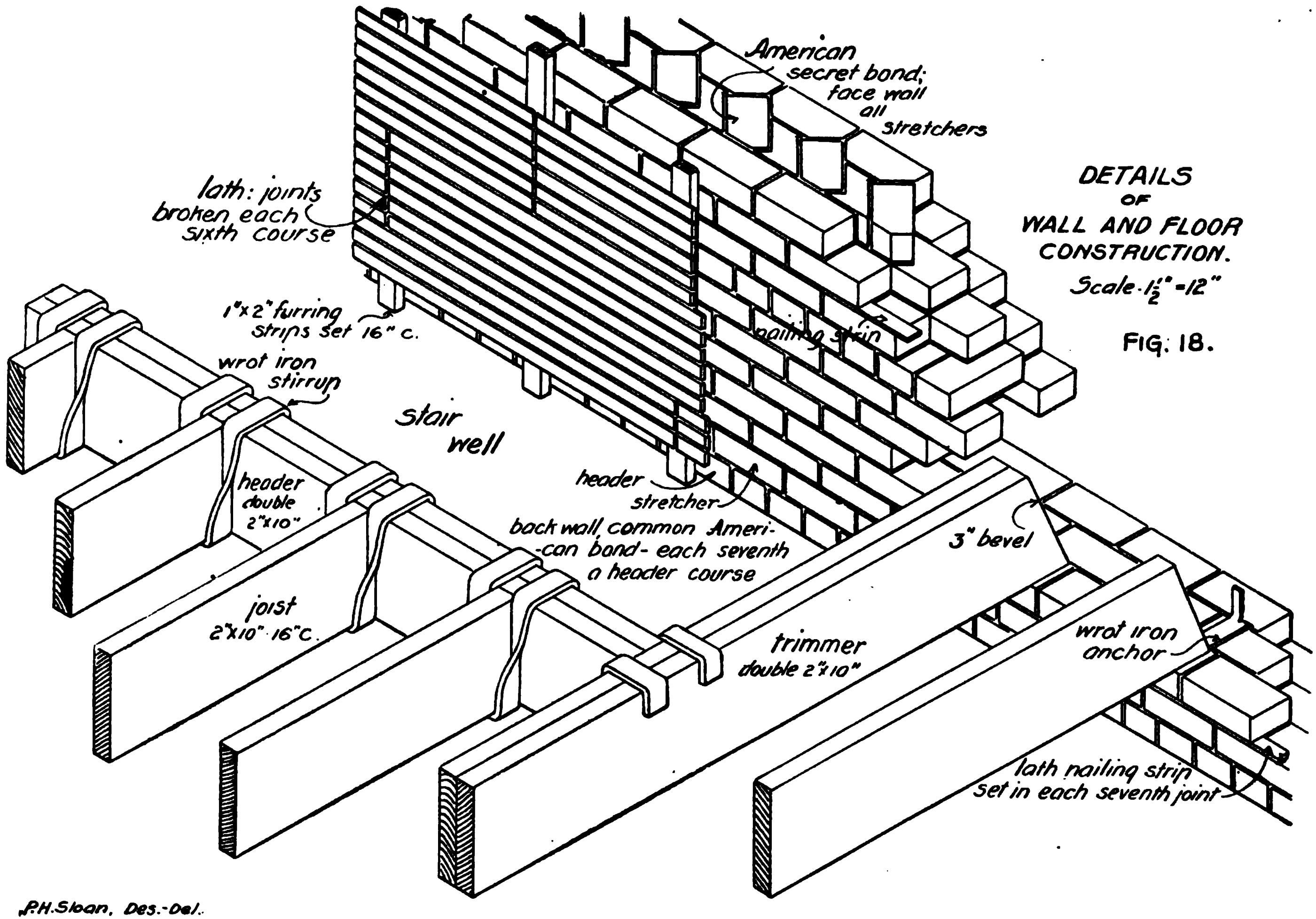

RESIDENCE AT
FOR
A.B.C. Archt.
Sheet 5.
SIDE ELEVATION
Scale 1/4" = 12"
R.H. Sloan, Des.-Del.

FIG. 14.



DETAILS OF WALL AND FLOOR CONSTRUCTION.
Scale $1\frac{1}{2}$" = 12"

FIG. 18.

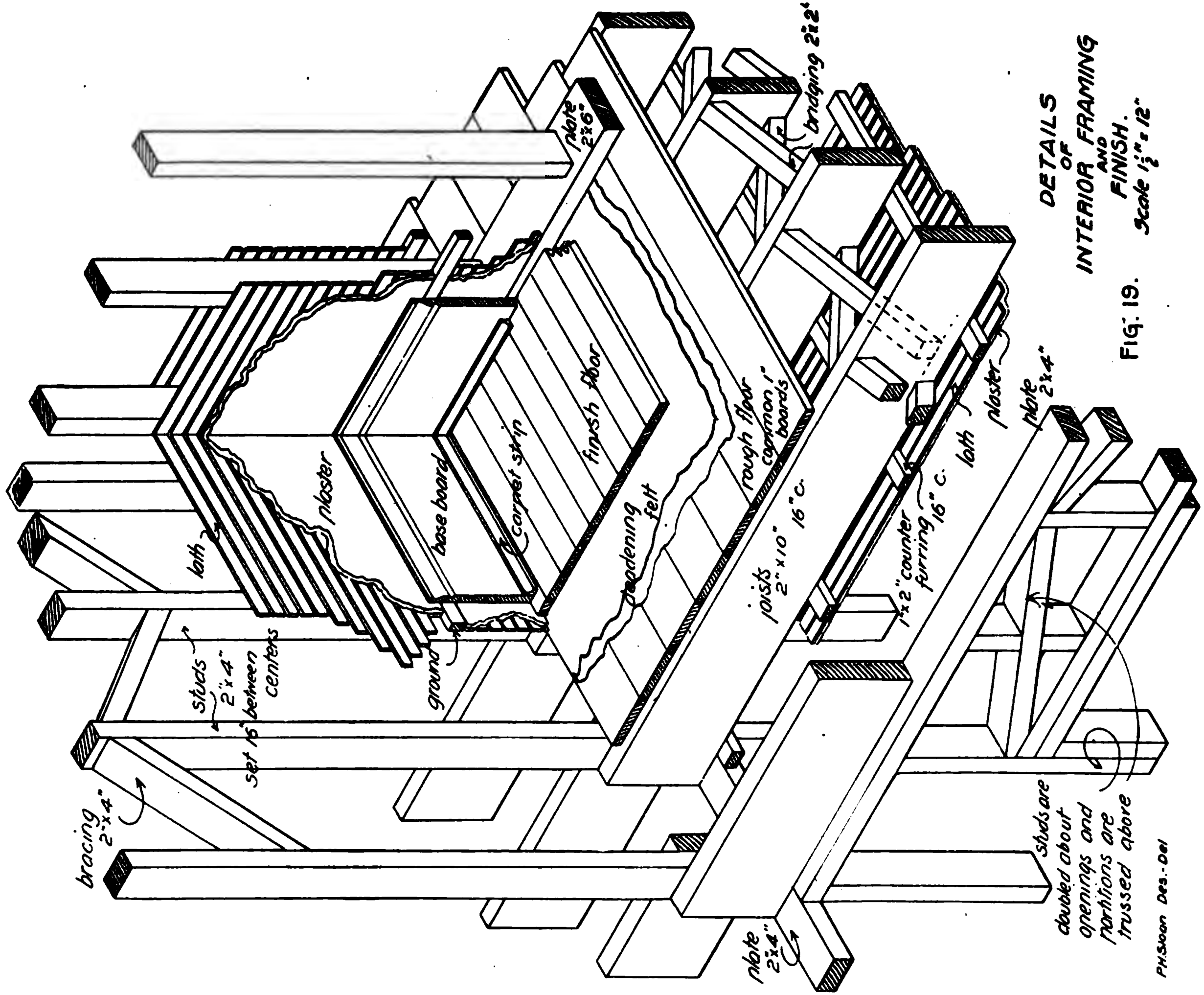


FIG. 19. DETAILS OF INTERIOR FRAMING AND FINISH. Scale $1\frac{1}{2}"=12"$

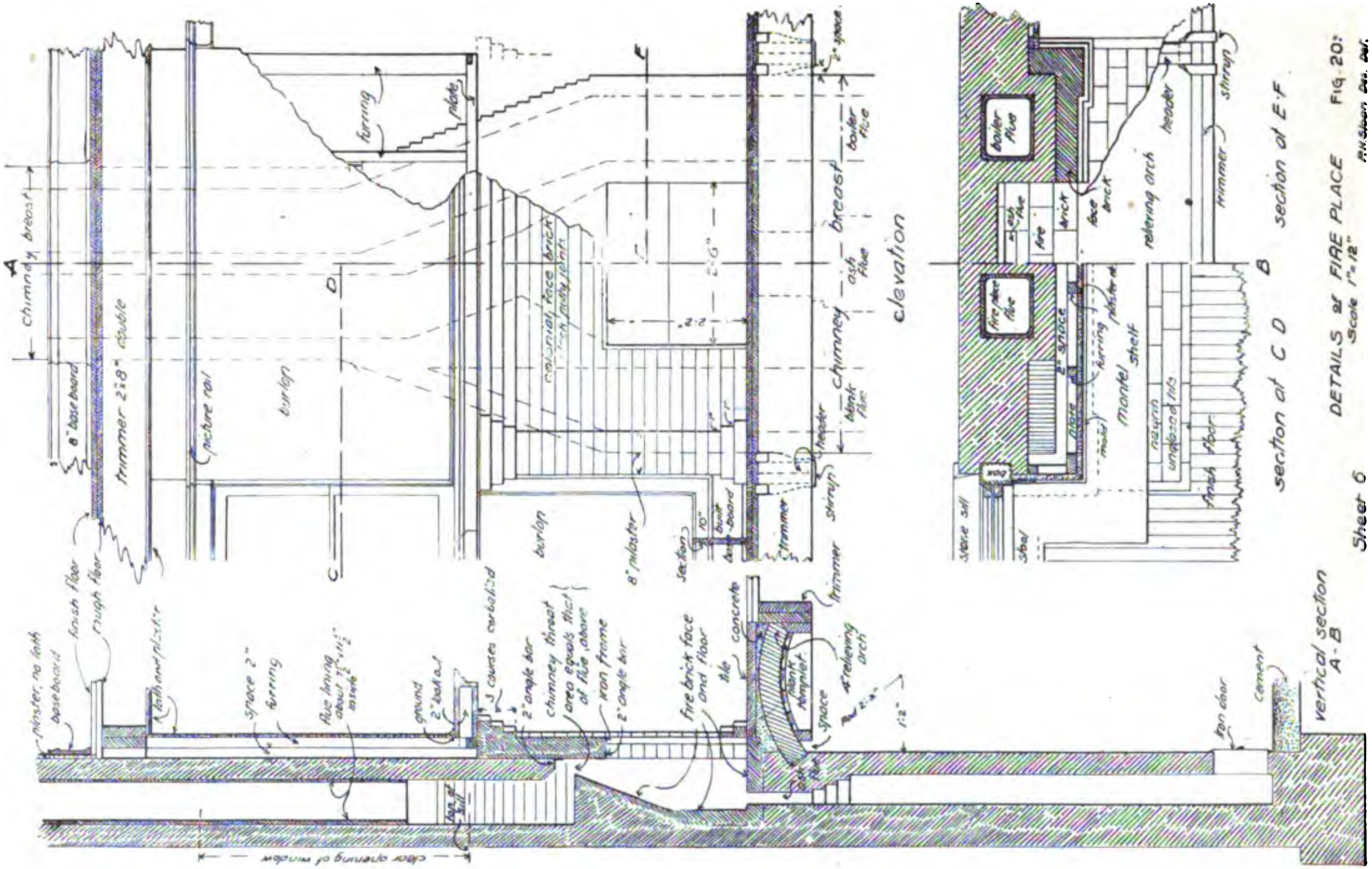


Fig. 20: DETAILS of FIRE PLACE Scale 1"=12"

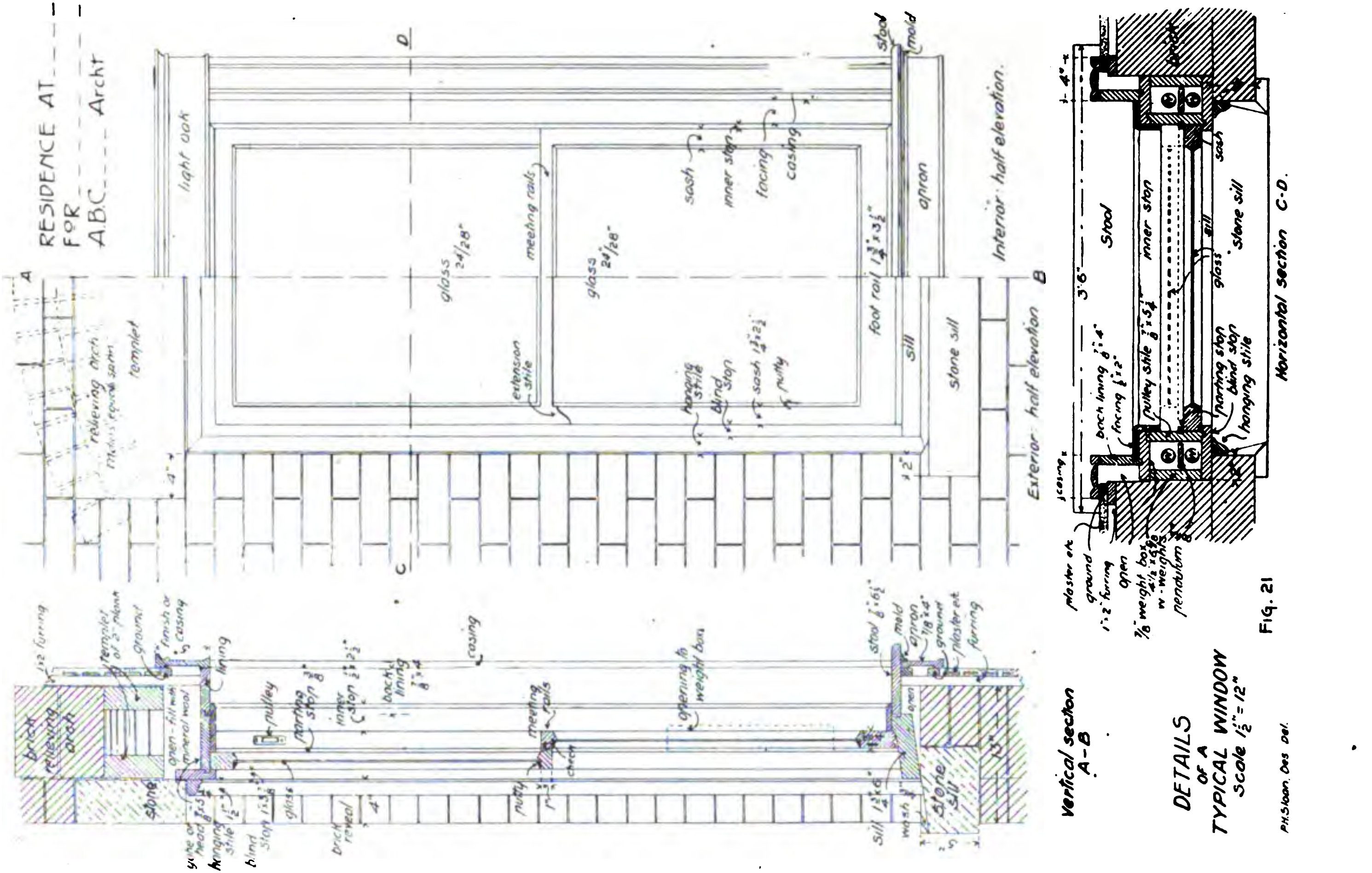
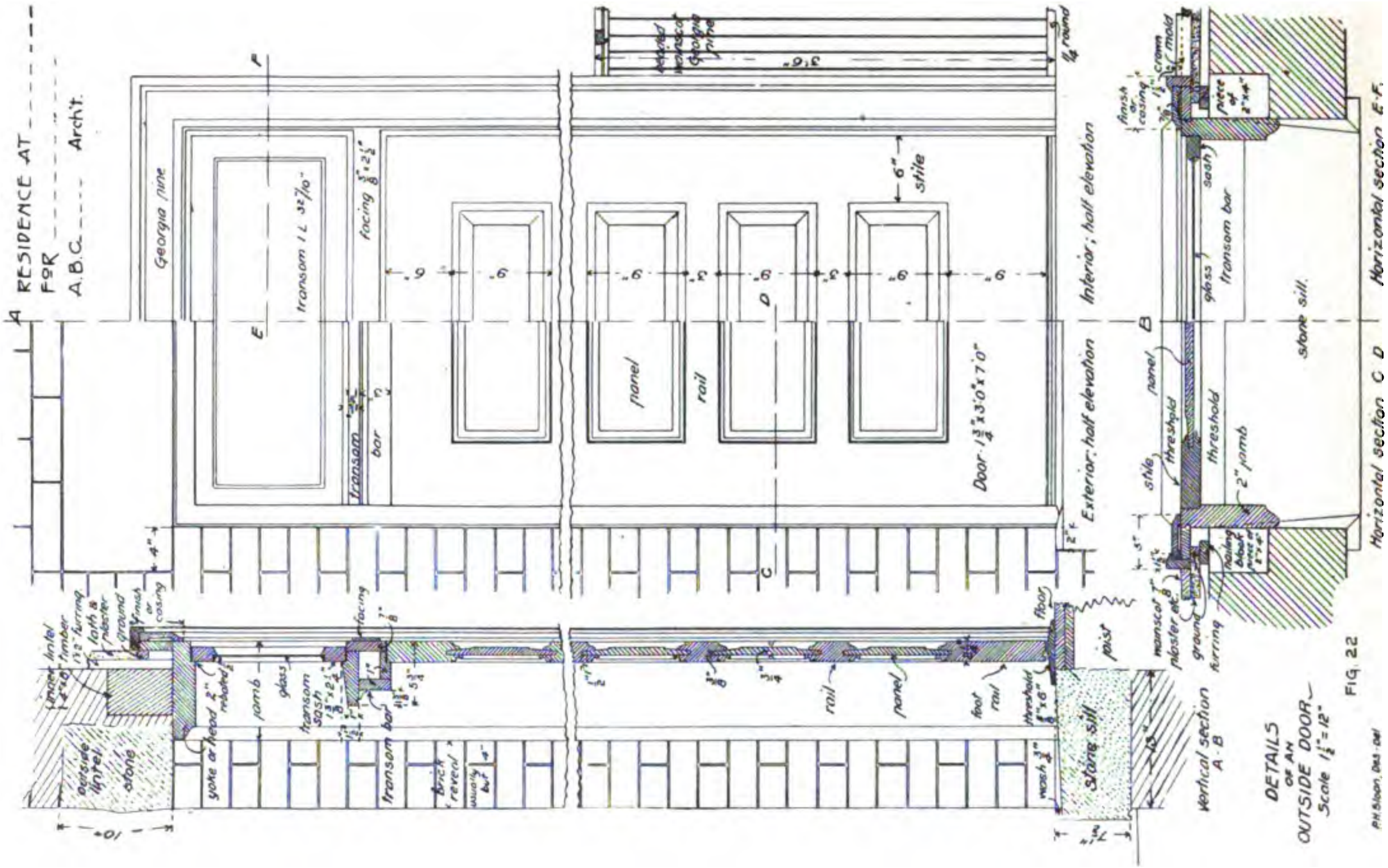

RESIDENCE AT
FOR
A.B.C. Archt
Exterior half elevation
Interior half elevation
Vertical section A-B
Horizontal section C-D
DETAILS OF A TYPICAL WINDOW
Scale 1½" = 12"
P.H.Sloan, Des. Del.

Fig. 21



RESIDENCE AT
FOR
A.B.C.
Arch't.
Georgia pine
transom 1 L 32"/10"
facing
panel
rail
stile
Door 1¾" x 3'0" x 7'0"
Interior; half elevation
Exterior; half elevation
Horizontal section E-F
Horizontal section C-D
stone sill
threshold
2" jamb
glass
transom bar
sash
floor
joist
Vertical section A-B
DETAILS OF AN OUTSIDE DOOR
Scale 1½"=12"
FIG. 22

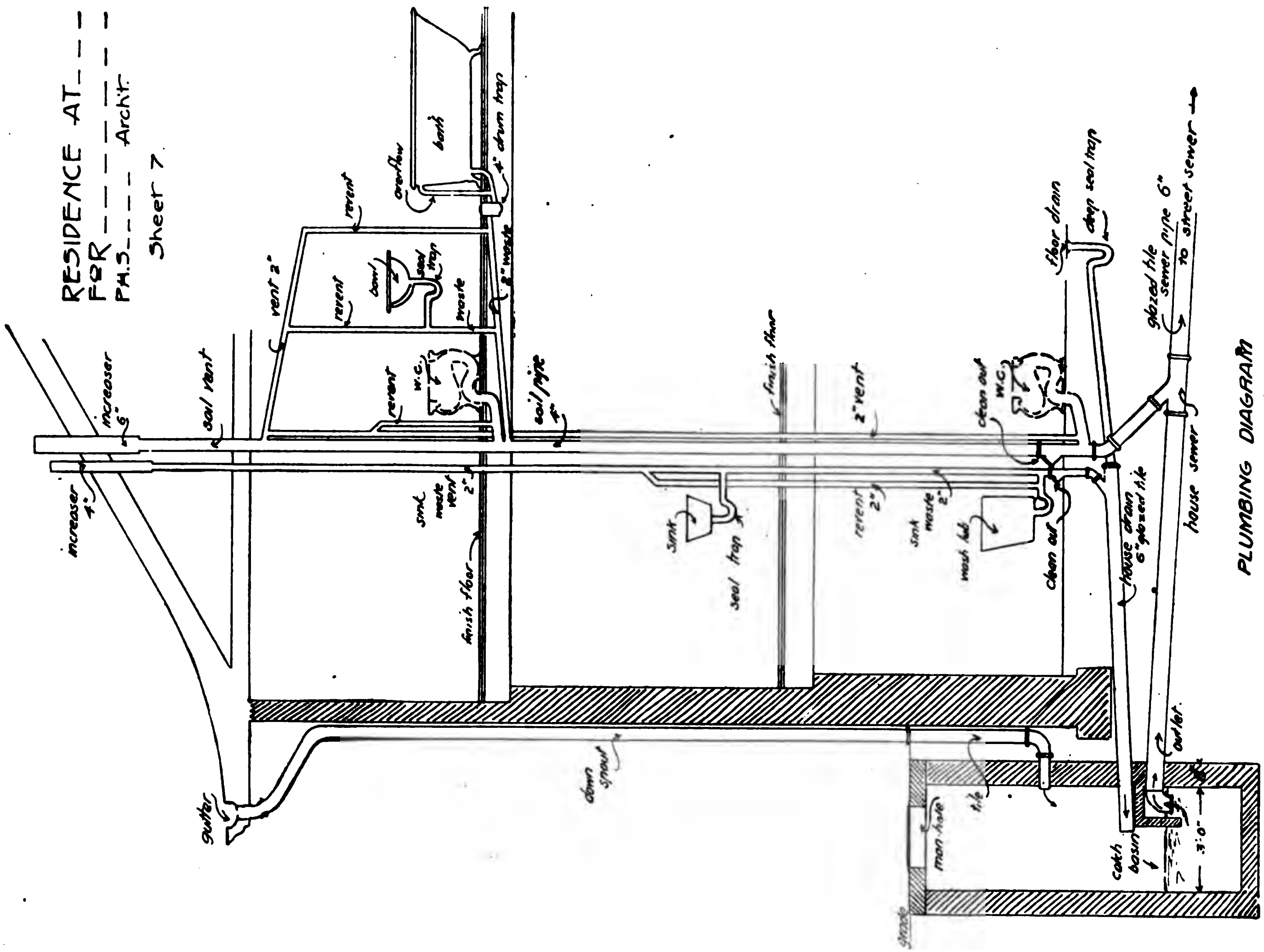
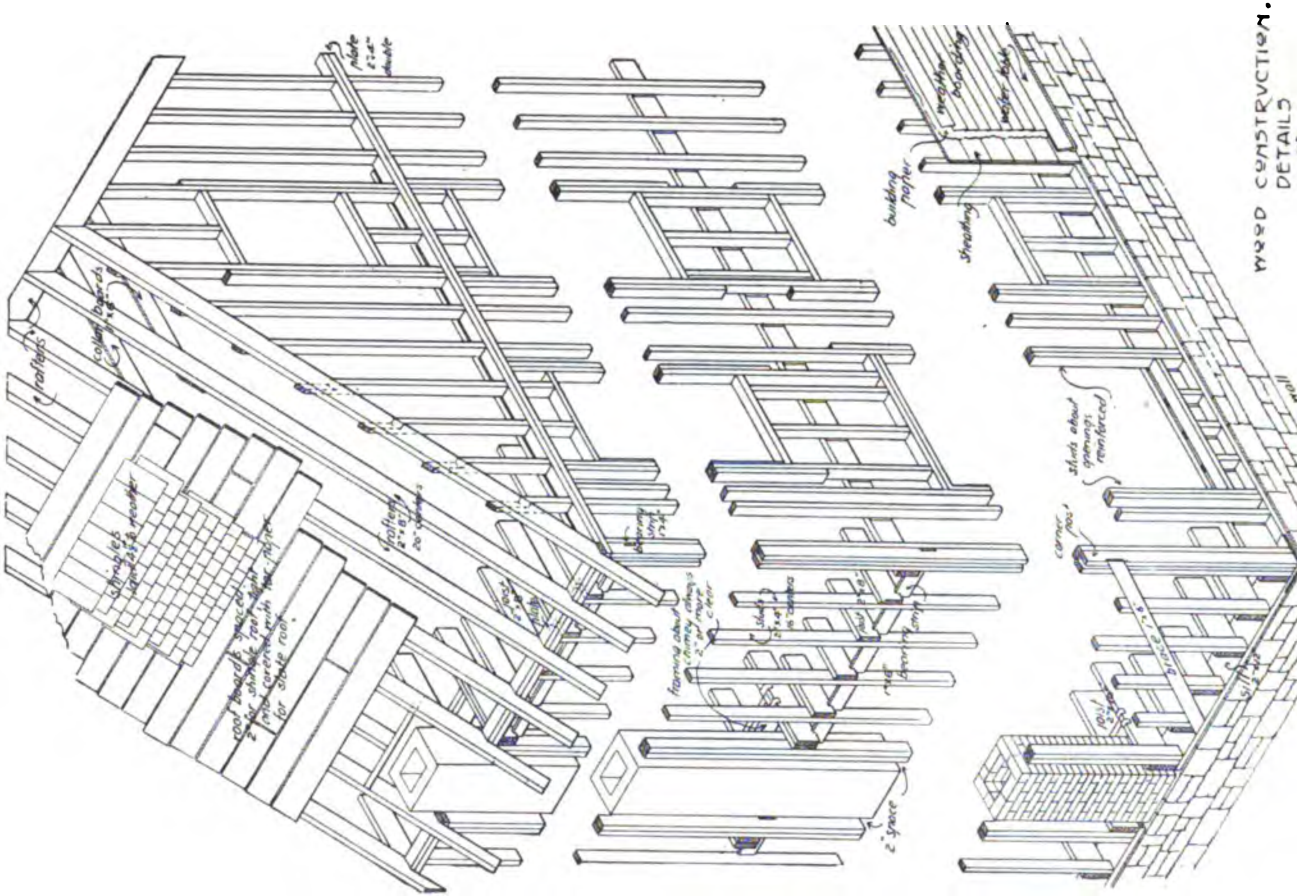


FIG. 25. PLUMBING DIAGRAM Scale $\frac{3}{8}$" = 12"

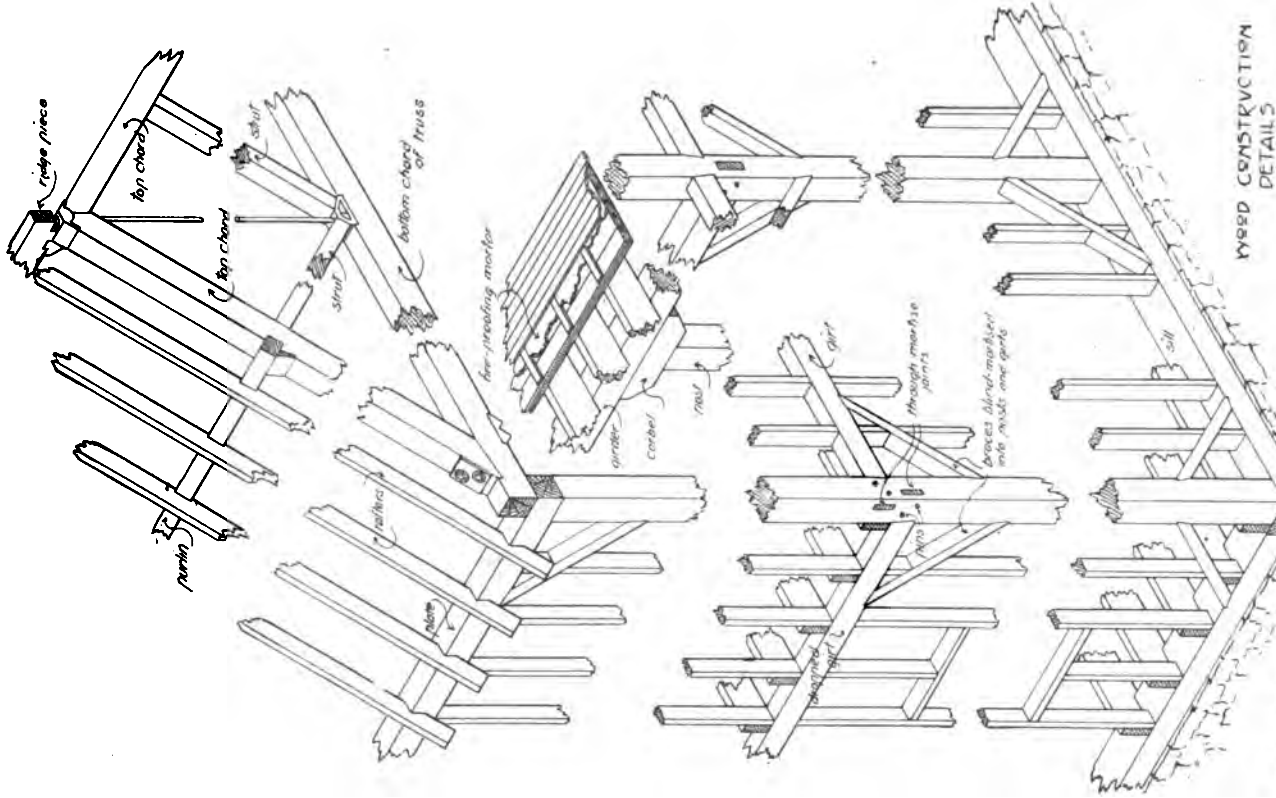
P.H.Sloan Des: Del.



WOOD CONSTRUCTION. DETAILS OF BALLOON FRAMING

ARCHITECTURAL DRAWING

FIG 27

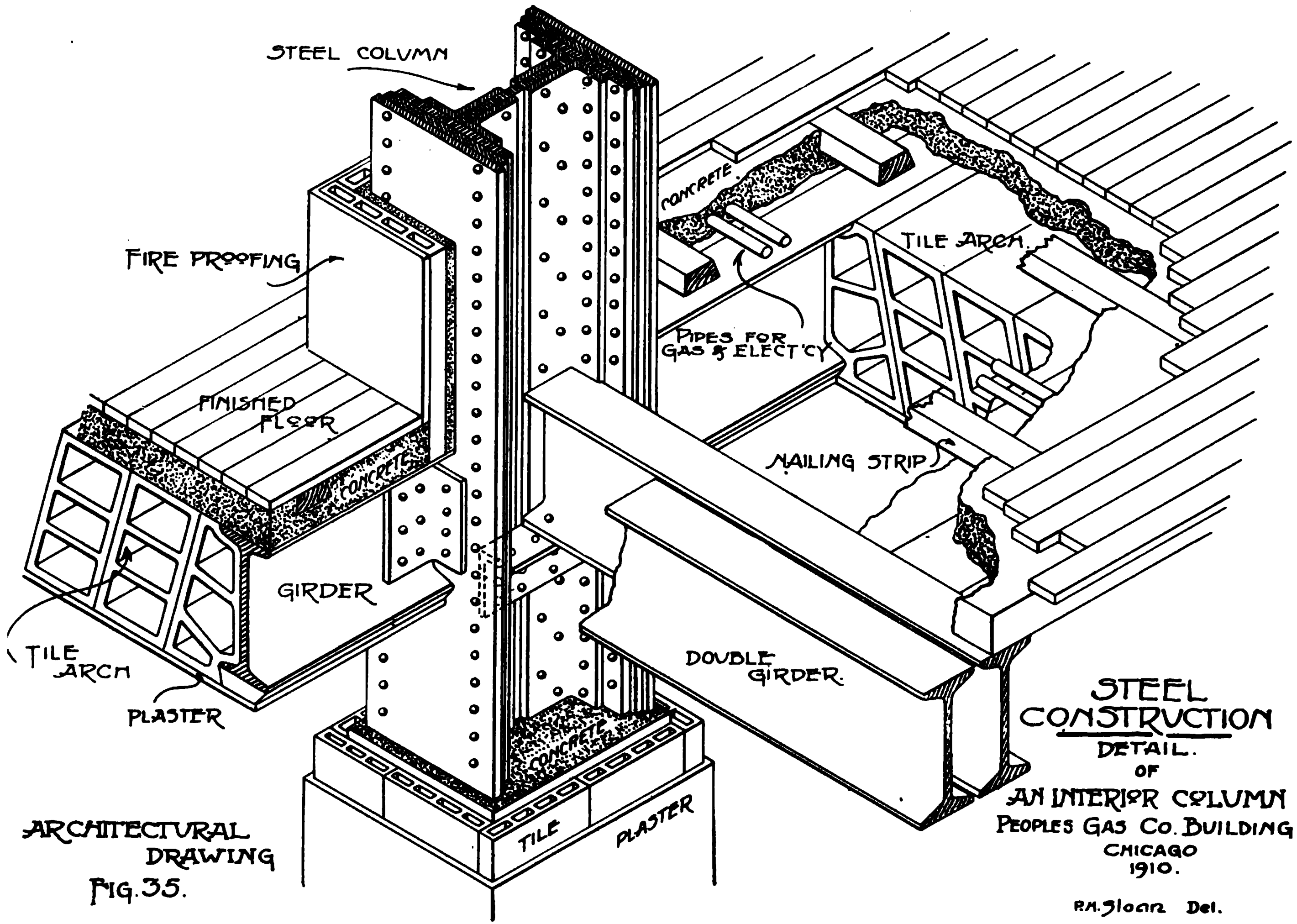


WOOD CONSTRUCTION DETAILS OF MILL FRAMING

P.M. Sloan. Des-Del.

ARCHITECTURAL DRAWING

FIG 34



ARCHITECTURAL DRAWING
FIG. 35.

INDEX

COURSE A—SHADOW PROJECTIONS.

COURSE A—LINEAR PERSPECTIVE.

PERSPECTIVE OF SHADOWS—COURSE A.

COURSE B—MACHINE DRAWING.

COURSE C—ARCHITECTURAL DRAWING.

[illegible]